TAMPERE UNIVERSITY OF TECHNOLOGY

EMMA PUOTUNEN

IMPACT OF NEW PRODUCT DEVELOPMENT DECISIONS ON SUPPLY CHAIN

Master of Science Thesis

Prof. Miia Martinsuo and Assistant Prof. Ilkka Kouri have been appointed as the examiners at the Council Meeting of the Faculty of Business and Technology Management on September 9th, 2012.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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There is no previous research on how new product supply chain is formed as a result of new product development decisions. As a consequence, the purpose of this thesis is to examine the decision making related to a new product and its supply chain. The target is to clarify which decisions, made during the new product development project, are important from the view of supply chain management and how these decisions should be made in order to improve a company's competitive performance in global markets. The main research question is formulated as follows: *What supply chain decisions do companies make as part of their new product development project and how can these decisions affect companies' performance in a global environment?* The underlying perspective of the thesis is the alignment of new product development and supply chain management.

The thesis is a preliminary study for potential wider research, and the focus is on Finnish manufacturing companies that operate in global markets. In order to reveal current practices in the companies, the study is conducted using multiple case study method. In total, three case companies were involved in the research.

As a result of this thesis, a framework is provided to support the decision making during new product development projects. The framework clarifies which decisions should be made at which stage and how the decisions reflect to each other. The main finding of this thesis is that in order to achieve better alignment between new product and its supply chain, the supply chain related issues should be taken into account already at the early stages of new product development project. It is suggested, that target setting during early stages should include also supply chain related issues instead of only focusing on new product specifications. Furthermore, supply chain strategy should guide the new product development project more explicitly, which could improve company's performance in global environment.

TIIVISTELMÄ

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PUOTUNEN, EMMA: Tuotekehityksen aikana tehtävien päätösten vaikutukset toimitusketjuun
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Aikaisempaa tutkimusta siitä, miten uuden tuotteen toimitusketju muodostuu tuotekehityksen aikana tehtävien päätösten perusteella, ei ole. Tämän tutkimuksen tarkoituksena onkin tutkia uuteen tuotteeseen ja sen toimitusketjuun liittyvää päätöksentekoa. Tutkimuksen tavoitteena on selventää, mitkä tuotekehitysprojektin aikaiset päätökset ovat tärkeitä toimitusketjun hallinnan näkökulmasta, ja miten nämä päätökset tulisi tehdä, jotta yrityksen suorituskyky globaaleilla markkinoilla paranisi. Päätutkimuskysymys on muotoiltu seuraavasti: *Mitä toimitusketjupäätöksiä yritykset tekevät osana uuden tuotteen kehitysprojektia ja miten kyseiset päätökset voivat vaikuttaa yrityksen kilpailukykyyn globaalissa ympäristössä?* Tutkimuksen näkökulmana on tuotekehitykseen ja toimitusketjun hallintaan liittyvien toimintojen yhdentäminen.

Tutkimus on esiselvitys mahdolliselle laajemmalle tutkimukselle. Tutkimuksen kohderyhmänä ovat suomalaiset valmistavan teollisuuden yritykset, jotka toimivat globaaleilla markkinoilla. Jotta yritysten tämän hetkisiin käytäntöihin saataisiin lisäselvyyttä, tutkimus suoritettiin käyttäen monitapaustutkimusmenetelmää. Yhteensä tutkimukseen osallistui kolme yritystä.

Työn tuloksena esitetään viitekehys, joka tukee tuotekehitysprojektin päätöksentekoa. Viitekehyksen tarkoituksena on selventää sitä, mitkä päätökset tulisi tehdä projektin missäkin vaiheessa ja miten eri päätökset vaikuttavat toisiinsa. Tutkimuksen päätuloksen mukaan toimitusketjuun liittyvät asiat tulee huomioida jo tuotekehitysprojektin varhaisessa vaiheessa, jotta tuotekehitykseen ja toimitusketjun hallintaan liittyvien toimintojen yhdentäminen olisi mahdollista. Tutkimuksen perusteella suositellaan, että projektin alussa asetettavien tavoitteiden tulisi sisältää toimitusketjua koskevia asioita tuotemäärittelyn lisäksi. Myös toimitusketjustrategian tulisi selkeämmin ohjata uuden tuotteen kehitysprojektia, mikä voisi parantaa yrityksen suorituskykyä globaalissa ympäristössä.

PREFACE

This thesis is dedicated to my grandmother “Mamma” and grandfather “Pappa”, who both passed away in late autumn 2012. Thank you for all your care and wise words, I try to remember them throughout my life.

Since writing this thesis has included both ups and downs, I owe my greatest thanks to my family and friends. Thanks to you, the autumn was not as hard as it would otherwise have been. Especially, I would like to express my gratitude to Lauri, who was always there when needed.

Finally, I want to thank my advisors Miia Martinsuo and Ilkka Kouri, everyone participating in the interviews and my colleagues at the Department of Industrial Management. Without you, writing this thesis would not have been possible.

Helsinki, February 20th, 2013

Emma Puotunen

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1. INTRODUCTION

1.1. Theoretical background

Based on different reports up to 80 per cent of the total costs of the supply chain are determined at the product design stage (Dowlatshahi 1996). As a consequence, an increasing interest on the coordination of supply chain management and new product development has emerged. The special issue of the Journal of Product Innovation Management focuses on the nexus of new product development and supply chain management processes (Hult & Swan 2003, Hult 2003). Furthermore, Journal of Operations Management published a special issue titled *Coordinating product design, process design, and supply chain design decisions* (Rungtusanatham & Forza 2005).

Van Hoek & Chapman (2006) state that existing research stresses the need to link supply chain issues into new product development so that the product availability can be ensured at the launch date. Furthermore, they state that the future research should focus on how product development can leverage supply chain capabilities in order to drive revenue growth and market impact. In recent years the research has focused on the product and supply chain variables that should be matched (Abdelkafi et al. 2010; Pero et al. 2010), and the determinants of aligning supply chain portfolios with product portfolios (Langenberg et al. 2012). On the other hand, there are also studies investigating how supply chain strategy should be aligned with the product (e.g. Stavrulaki & Davis 2010). These studies are continuing the research stream started by Fisher (1997). Furthermore, there are studies investigating the effects of the alignment on supply chain performance (e.g. Khan et al. 2012).

However, there is no previous research on how the alignment can be actually achieved. In other words, there is no research on how supply chain for new product is formed as a result of new product development project. As a consequence, this thesis tries to explore the decision making process related to the new product and its supply chain.

1.2. Research objectives

Main objective of this thesis is to increase the understanding on what supply chain related decisions companies make during the new product development project and how these decisions should be made in order to improve company's competitive performance in global markets. Resulting from the research objectives, the main research question is formulated as follows:

What supply chain decisions do companies make as part of their new product development project and how can these decisions affect companies' performance in global environment?

The main research question can be divided into three sub-questions:

- *What supply chain issues do companies deal with during new product development project?*
- *How and in which context are supply chain related decisions made during new product development project?*
- *What challenges are there related to global supply chains?*

This thesis is a preliminary study for potential larger research. As a consequence, besides trying to widen the understanding of the current situation, the object is to collect needs for future research.

1.3. Thesis structure

The thesis is organized as follows. Next, in chapter two, the literature is reviewed in order to build a theoretical foundation for the whole thesis. The first part of the literature review focuses on the alignment of new product development and supply chain management. After that tactical new product development decisions are studied in order to understand, what the main decisions made during the new product development process affecting supply chain management are. In the next part supply chain management literature is further reviewed in order to understand what requirements and challenges there are for successful decisions. As a result, a conceptual decision making framework is provided. The last part of chapter two focuses on concepts and practices that may improve the alignment of new product development and supply chain management.

In chapter three the research methodology is described. The chapter includes a short overview of selected research strategy and information on how empirical data was collected and analyzed. Also a short description of case companies is provided. Chapter four is dedicated to case study results. The results are presented with respect to the findings of the literature review. Both the NPD decisions and the alignment practices identified in the literature review are discussed, after which the challenges in operating in global environment are represented.

Chapter five includes discussion on the case results linking them to previous research on the issue. Furthermore, a revised framework for decision making during NPD process is provided. The chapter is probably the most important part of this thesis. Finally, in chapter six, managerial implications, academic contribution and limitations are represented. In order to enhance the future research about the issue also future research needs are suggested.

2. LITERATURE REVIEW

2.1. Aligning new product development and supply chain management

The alignment of new product development and supply chain management forms the core idea of this thesis. In this chapter these broad concepts are further defined and analyzed.

2.1.1. New product development

Krishnan & Ulrich (2001) define new product development (NPD) "as the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale". It is information- and knowledge-intensive work (Clark & Fujimoto 1991). As Hong et al. (2004) state, firms' superior product development capabilities are derived from their ability to create, distribute and utilize knowledge throughout the product development process.

Ulrich & Eppinger (2008) categorize product development projects into four types:

1) new product platforms,
2) derivatives of existing product platforms,
3) incremental improvements to existing products, and
4) fundamentally new products.

New product platform development projects involve a major development effort to create a new product family based on a new, common platform. The products are targeted to familiar markets. Product platform is a technological foundation of the product family and it serves as the base architecture for a series of derivative products (Meyer et al., 1997). In contrast, d*erivative of existing product platform* projects extend an existing product family with one or more products. The objective of the project is also addressing familiar markets. (Ulrich & Eppinger 2008.) The product family can be defined as a set of final products that are offered by a single company, are partially substitutable in their demands, possess similarities in their functionality, and share the same common design and assembly process (Salvador et al. 2002, Gupta & Krishnan 1998). Projects that aim to *incremental improvements to existing products* involve adding or modifying some features of existing products. The objective is to keep the product line current and competitive. Development project of *fundamentally new products* involve development of radically different product or production technologies and may target new and unfamiliar markets. Such projects involve usually high risk, but however, may improve long-term success (Ulrich & Eppinger 2008).

The complexity of product development projects varies too. Ulrich & Eppinger (2008) demonstrate the range of complexity in comparing Stanley Tools screwdriver with Boeing 777 airplane: the screwdriver requires a development team of about six people and total budget of $300 000 whereas the airplane requires a development team of thousands of people and a budget of $6 billion. As a consequence, product development projects can be roughly divided into two types; product development in the small and product development in the large (Eppinger et al. 1994; Fine 1998). Fine (1998) states, that if the entire project can be managed in a face-to-face manner, then it is a small project. In contrast, the project is called large one, if the team size and the distance require communication with layers of organization or constant use of interactive technology.

According to the Product Development & Management Association (PDMA) best-practices study, 69 per cent of firms report using a formal, cross-functional process for new product development (Barczak et al. 2009). Most of the firms use some kind of stage-gate process, in which the product development has been broken into a predetermined set of stages. Each stage consists of a set of prescribed, cross-functional and parallel activities. Before each stage there is an entry gate or a go/kill decision point. (Cooper 1994.) A closer look at the activities in different stages reveals that they are actually information acquisition activities. The objective of every stage is to gather information needed to make decisions at the next gate. (Cooper 2008.) The key stages of a typical stage-gate process are shown in figure 2.1.

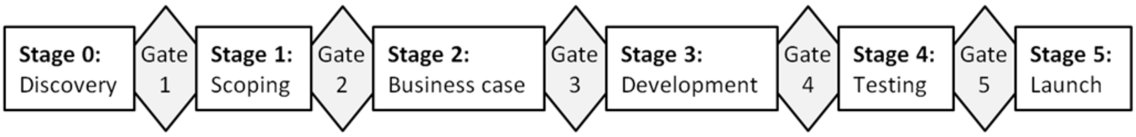

Figure 2.1. *Stage-gate process (adapted from Cooper 2008).*

The discovery stage includes discovering opportunities and generating new product ideas. After a go decision from the gate, it is time for the scoping stage, in which a quick, preliminary investigation and scoping of the project are done. The second stage includes a detailed investigation involving primary research, both market and technical, which leads to a business case. The business case includes the product definition, the project justification, and a project plan. The third stage, the development stage, involves the actual detailed design and development of the new product and some product testing. Also the full production and market launch plans are developed in this stage. The testing stage includes test and trials in the marketplace, lab and plant to verify the proposed product and its marketing and manufacturing or production plan. The final stage, the launch, includes commercialization and the beginning of full manufacturing or production, marketing and selling. (Cooper 2008.)

The stage-gate process has been shown to be effective in stable conditions but its usability has been questioned in uncertain and dynamic environments. Different phased product development systems encourage heavy up-front planning followed by sticking to the plan. When applied to high-risk, highly innovative programs, they have had an unnoticed side effect of putting innovation in a straitjacket, thus making it difficult to make changes during the projects (Flexible product development, 2008). Also MacCormack et al. (2001) state, that more flexible processes are required in industries, where development teams face extreme levels of uncertainty. They suggest that in a flexible process, development team must focus on getting an early version of the product into customers' hands as soon as possible.

2.1.2. Supply chain management

A supply chain is "an integrated process wherein a number of various business entities (i.e., suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials/components, (2) convert these raw materials/components into specified final products, and (3) deliver these final products to retailers" (Beamon 1998). However, as Lambert & Cooper (2000) state, supply chain is not a chain of businesses with one-to-one, but a network of multiple businesses and relationships. Also Christopher (2011) emphasize the idea of network as he state that the word 'chain' should be replaced by 'network' since there are normally multiple suppliers and customers in the total system. Mentzer et al. (2001) define supply chain as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer."

Porter (1985) introduced the concept of value chain. It has been called as the underlying framework of supply chain (Skjøtt-Larsen et al. 2007). Porter (1985) described a series of primary activities that add value to the output of the firm: inbound logistics, operations, outbound logistics, marketing and sales and services. The primary activities are supported by support activities: infrastructure, human resource management, technology development and procurement. To gain competitive advantage a firm must deliver value to its customers performing these activities more efficiently than its competitors or performing the activities in a way that creates greater differentiation. In Porter's model the focus is on the focal firm. Christopher (2011, p. 11) states that because of outsourcing, the value chain has been extended beyond the boundaries of the focal firm, and the supply chain has become the value chain. As such, value is no more created only by the focal firm in the network but by all the entities that are connected to each other.

Mentzer et al. (2001) consider the existence of different degrees of supply chain complexity. They distinguish between a *direct supply chain*, an *extended supply chain* and an *ultimate supply chain*. A direct supply chain consists of a focal company and its direct supplier and customer. An extended supply chain includes suppliers of the direct supplier and customers of direct customer. The ultimate supply chain on the contrary includes all the organizations involved in all the upstream and downstream flows of products, services, finances, and information from the ultimate supplier to the ultimate customer. It is noteworthy, that the supply chain will look different depending on a firm's position in it (Croxton et al. 2001). Lambert et al. (1998) illustrate how complicated an extended supply chain can be. The illustration is presented in figure 2.2. Furthermore, multiple products are often involved in a supply chain. The products may share similarities in terms of the components, characteristics, and associated manufacturing processes despite distinctive features in terms of marketability and functionality. Such similarity and dissimilarity across the product range have significant impact on the optimal supply chain. (Huang et al. 2005.)

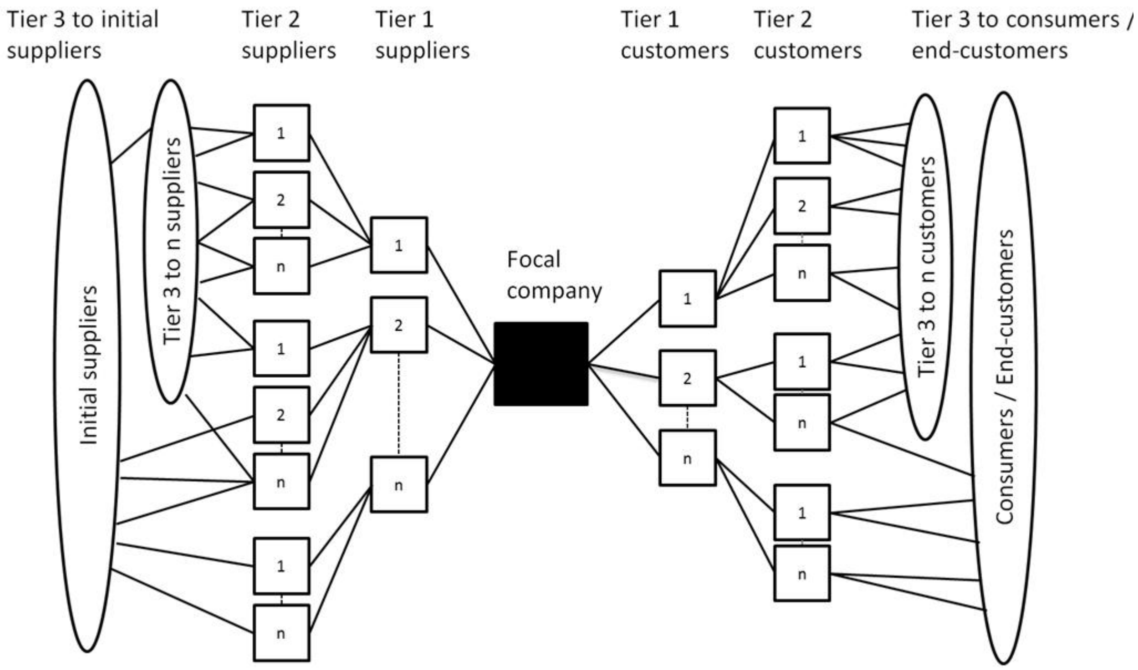

Figure 2.2. *Supply chain network structure (Lambert et al. 1998).*

Thomas & Griffin (1996) state that there are three traditional stages in a supply chain: procurement, production and distribution. Each of the stages can composed of several facilities in different locations around the world. Beamon (1998) on the contrary states that a supply chain is comprised of two integrated processes: the production planning and inventory control process and the distribution and logistics process. Mabert & Venkataramanan (1998) propose five major stages. The first stage, *sourcing*, involves the supply of raw materials and components through a network of vendors, as well as product development support through subassembly design and tooling production for process changes. *Inbound logistics* focuses on movement and storage of required materials to meet production schedules. *Manufacturing* should produce a high quality and price competitive product. *Outbound logistics* focus on movement of finished goods through the distribution network to global markets for end user. The final stage, *after-*

market service, recognizes the need to support the product either through replacement parts and repair service, or customer service.

A broader concept of supply chain is supply chain management (SCM). However, the generally accepted definition of supply chain management (SCM) is missing. Accordingly, Bechtel & Jayaram (1997, p. 19) identified five supply chain management schools of thought:

- *Functional chain awareness*, where chain of functional activities forms the basis for material flow.
- *Linkage/logistics* emphasizes the linkages between functional areas and the focus is on logistics and transportation
- *Information* emphasizes the information flow in both directions within the chain.
- *Integration* emphasizes the integration of processes across the supply chain in order to generate customer satisfaction.
- *A future perspective* aims to develop a demand driven seamless pipeline emphasizing both relations and transactions.

At the moment, the broader understanding of supply chain management is emerging. Lambert & Cooper (2000) define it as the management of multiple relationships across the supply chain. According to Christopher (2011) the definition of supply chain management is "the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole." On the contrary, The Global Supply Chain Forum define the supply chain management as follows: "Supply chain management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Lambert et al. 1998). Accordingly, supply chain management offers an opportunity to capture the synergy of intra- and intercompany integration and management. Supply chain management seeks to linkage and co-ordination between the processes or other entities in the pipeline, i.e. suppliers and customers, and the organization itself (Christopher, 2011). Also Vickery et al. (1999) state, that "supply chain management seeks to enhance competitive performance by closely integrating the internal functions within a company (e.g., marketing, product design and development, manufacturing) and effectively linking them with the external operations of suppliers and channel members". Huang et al. (2002) state, that the idea of supply chain management is to view the chain as an integrated system, and to fine-tune the decisions about how to operate the various components in ways that can produce the most desirable overall system performance in the long run. From these definitions, one can conclude the supply chain management to include both the management of multiple relationships and different business processes across the supply chain in order to add value for end customers.

Cooper et al. (1997) propose a framework of supply chain management, which is presented in figure 2.3. The framework consists of three elements: business processes, management components, and the structure of the supply chain. The supply chain business processes includes customer relationship management, procurement, customer service management, demand management, order fulfillment, manufacturing flow management, product development and commercialization, and returns management (Cooper et al. 1997, Croxton et al. 2001). The idea behind the processes is that the logistics process is not the only process that cuts across supply chain. The truth is, that basically all business processes cuts inter-organizational boundaries and sometimes it happens independently of formal structure (Cooper et al. 1997). Croxton et al. (2001) further note, that the mentioned processes are designed from the perspective of a manufacturing company sitting near the middle of the supply chain.

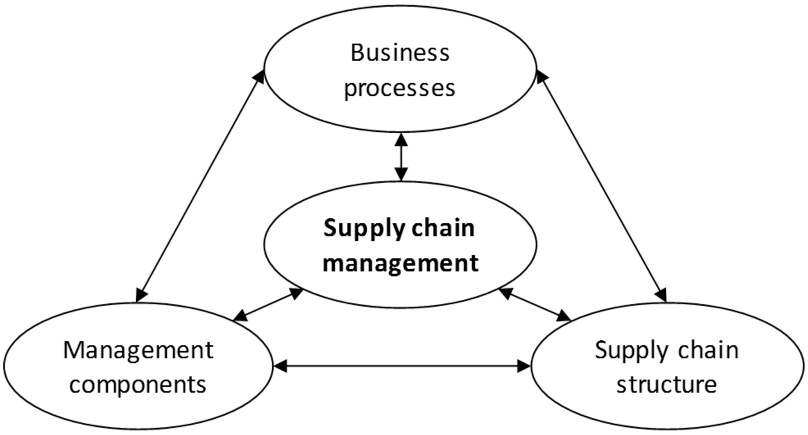

Figure 2.3. *Framework for supply chain management (Cooper et al. 1997).*

The management components in the framework determine how the business processes, and thus the supply chain, are managed and structured. The extent to supply chain must be managed depends on several things, such as the complexity of the product and availability of raw materials. The dimension to consider includes also the supply chain structure. The structure may vary according to the length of the supply chain, the number of suppliers and customers at each level, the closeness of the relationships at different points and so on. (Cooper et al. 1997.)

In this thesis the focus is on the management of different business processes across the supply chain in order to add value for the end customers. However, the specific object is to study how company can enhance competitive performance by integrating the internal functions and effectively linking them with the external operations of suppliers and channel members. The supply chain is investigated based on the stages proposed by Mabert & Venkataramanan (1998). As mentioned earlier, they are sourcing, inbound logistics, manufacturing, outbound logistics and aftermarket service.

2.1.3. Alignment of NPD and SCM

Many companies already make significant efforts in designing their supply chain. However, often they do not recognize all the opportunities they would have if they focused on designing the supply chains strategically and concurrently with their products and production processes (Fine 1998, p.133). Especially, the issue is important when companies develop new products, for the product design stage creates the product to be manufactured and distributed within the supply chain, and thus determines large portion of the supply chain costs (Pero et al. 2010). In fashion industry the alignment of new product development and the supply chain management has been found not only to improve firm's competitive advantage but also improve firm's supply chain resilience and supply chain responsiveness (Khan et al. 2012). In a case study covering several industries the supply chain performance was noticed to depend on the match between new product development and supply chain design and management (Pero et al. 2010).

In the literature there is no detailed definition for alignment of new product development and supply chain management. The word alignment can be referred to consistency or fit (Acur et al. 2012). On the other hand, the "alignment of two processes" indicates that there is common objective among the process owners (Abdelkafi et al. 2010). Nevertheless, Pero et al. (2010) provide a framework for the alignment of NPD and SCM. In the framework the new product development variables include modularity, product variety and innovativeness while the supply chain variables include supply chain configuration, collaboration and coordination complexity. Based on a multiple case study covering several industries, they state that in order to increase the alignment the companies should design their products in way that supports the supply chain. The worst case corresponds to the situation when supply chain receives no support from product design, which means that the innovativeness and variety are high, and modularity is low.

An important supply chain consideration is whether or not the products can be manufactured according to the desired specifications and with the right materials in adequate supply and further delivered to the desired place using the most efficient packaging and transportations options (Khan et al. 2012). Thus, the target of the alignment is to secure that the developed products can be delivered at the targeted cost, time and quality (Pero et al. 2010). Therefore, new product development and supply chain management processes are highly dependent on each other. Hult & Swan (2003) offer a framework as an incentive to study interdependencies between product development and supply chain management. The framework includes six subprocesses for product development management process and ten subprocesses for supply chain management process. The framework is presented in figure 2.4. However, the framework is not further studied and the interdependencies between NPD and SCM are still rather unsolved. Especially, none of the scholars has investigated the interdependencies as a whole.

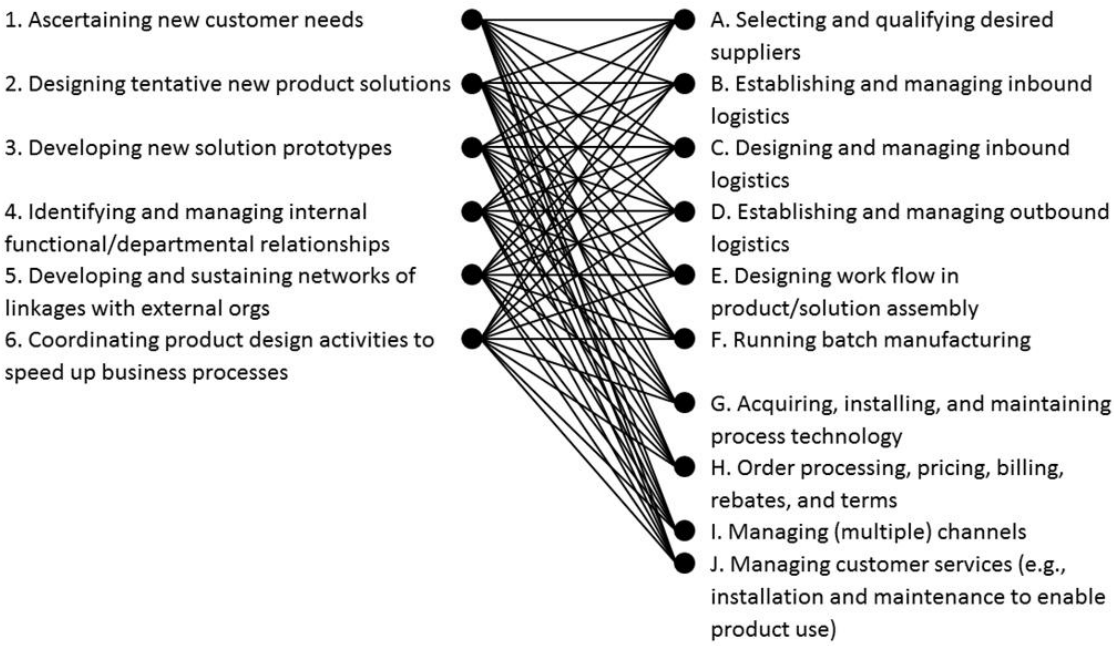

Figure 2.4. *Interface of product development and supply chain management sub-processes (Hult & Swan 2003).*

Van Hoek & Chapman (2006) developed a three-stage framework for improving new product development-supply chain alignment. The framework is illustrated in figure 2.5. The bottom horizontal axis shows product development's perspective on supply chain. The perspective progress from "Get the product out there", and "do it efficiently" to "leveraging supply chain capabilities to making NPD better". The point where the alignment occurs is showed at the top horizontal axis. The vertical axis indicates supply chain's perspective on NPD. The target is to form a joint mission with NPD to drive revenue growth and market impact.

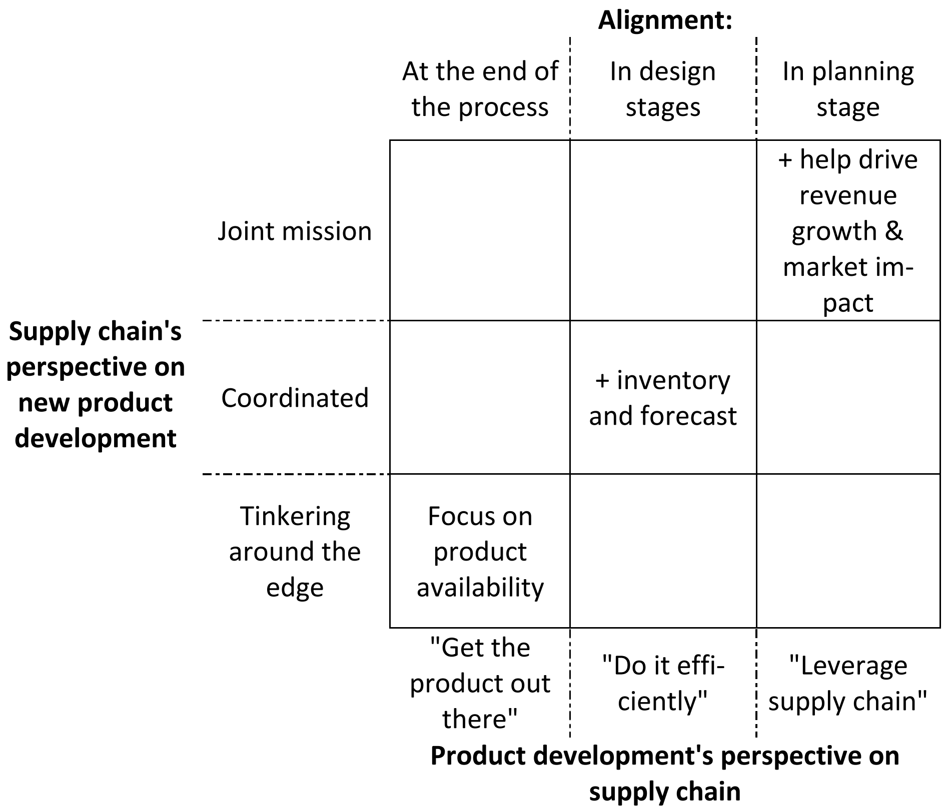

Figure 2.5 *Aligning product development and supply chain (van Hoek & Chapman 2006).*

Van Hoek & Chapman (2007) further present three steps that can be taken in order to move from tinkering around the edge to enhancing NPD impact. They are

1. improving basic alignment,
2. improving supply chain readiness, and
3. leveraging supply chain capabilities.

It was noticed in one case company that the basic alignment could be improved by increasing communication and training, and improving the initiative planning process. The supply chain readiness was instead improved in the second case company by creating a new role called new product introduction forecasting manager. It helped the company to avoid problems with limited product availability, disappointed customers and lots of firefighting efforts. In the third company the supply chain capabilities were leveraged better by co-locating staff with key suppliers to collaborate on NPD and to learn about new innovations. (van Hoek & Chapman 2007.)

Pero et al. (2010) has divided the approaches to product development and supply chain alignment into new product development (NPD) oriented and supply chain management (SCM) oriented approaches. The NPD-oriented approach pay attention to supply chain constraints at the early stages of product development and can be called *design for supply chain management*. The concept of design for supply chain management states that the product line, bill of materials, and product customization processes are designed so that logistics cost and customer service performance can be optimized (Lee & Sasser 1995). These ideas are partly discussed in the next chapter from the view of making new product development decisions. SCM-oriented approaches on the contrary assume that the product and its characteristics are given (Pero et al. 2010). This research stream is discussed in more detail in chapter 2.4.2.

2.2. New product development decisions

Krishnan & Ulrich (2001) argue that product development processes differ not across firms but even within the same firm over time. In order to generalize, the decision perspective offers more acceptable way to analyze product development; different organizations make different choices and use different methods, but all of them make decisions about a set of issues such as the product concept, product architecture, procurement, and distribution arrangements. Hultink et al. (1997) organize product development decisions into two categories: tactic and strategic decisions. Krishnan & Ulrich (2001) define tactic decisions as decisions made within the context of a single project in actually developing the product. Strategic decisions on the contrary refer to decisions a firm makes in establishing an organizational context and in planning development projects. Furthermore, these decisions set the objectives of a new product development project and control the process from a strategic level (McCarthy et al. 2006). In this thesis the focus is on the tactical level for the object of the thesis is to explore the decisions made during the product development process. In their extensive literature review Krishnan & Ulrich (2001) further divide tactic decisions into four categories: concept development, supply-chain design, product design, and production ramp-up and launch. The categorization is applied to this thesis also. In the next section these decisions are studied based on their effects on supply chain.

2.2.1. Concept development decisions

Krishnan & Ulrich (2001) propose five basic decisions to be made during the concept development: What are the target values of the product attributes? What will the product concept be? What variants of the product will be offered and which components will be shared across which variants? What is the product architecture? What will be the overall physical form and industrial design of the product? They also state that concept development decisions define the extended product offerings as life-cycle services and after-sale supplies.

Krishnan & Ulrich (2001) intend product attributes to refer to both customer needs and product specifications. Customer needs are usually rated based on their relative importance for customers and competitive analysis. Specifications provide an accurate description of what the product is supposed to do; they consist of a metric and a value. In an ideal world, the specifications are set once early in the development process and the product will be designed exactly according to them. However, this is quite unusual and especially for technology-intensive product the specifications are set at least twice. The early specifications are called as *target specifications*. The *final specifications* are set when the product concept has already been selected and tested. (Ulrich & Eppinger 2008, pp. 74-83.) At the same time as the product's technical features are defined also the product target-cost should be established. As Ellram (2000) states, "the target costs are based upon desired profit margin and projected selling price for the good or service, and reasonable estimates of what the item or service should cost".

Ulrich (1995) describes product architecture as the scheme by which the function of a product is allocated to its physical components. To be precise, the product architecture can be defined as "1) the arrangement of functional elements, 2) the mapping from functional elements to physical components, and 3) the specification of the interfaces among interacting physical components". Ulrich (1995) distinguishes between integral and modular product architectures. An integral architecture includes a complex mapping from functional elements to physical components and/or coupled interfaces between components. On the contrary, a modular architecture includes a one-to-one mapping from functional elements to the physical components and specifies decoupled interfaces between components. Modular architectures can be further divided into three subtypes: slot, bus and sectional. The differences lie in the way the component interactions are organized. In a slot architecture each of the interfaces between components are different and various components cannot be interchanged. In a bus architecture, there is a common bus to which components can be connected with same type of interface. In a sectional architecture, all interfaces are same type and there is no single main element to which all the rest components attach (Ulrich 1995). Tradeoffs between modular and integral architecture are presented in table 2.1.

Table 2.1. *Tradeoffs between modular and integral product architecture designs (Mikkola & Gassmann 2003).*

Benefits of modular designs	Benefits of integral designs
• task specialization • platform flexibility • increased number of product variants • economies of scale in component commonality • cost savings in inventory and logistics • lower life cycle costs through easy maintenance • flexibility in component reuse • shorter product life cycles through incremental improvements such as upgrade, add-ons and adaptations • independent product development • outsourcing • system reliability due to high production volume and experience curve	• interactive learning • superior access to information • systemic innovations • high levels of performance through proprietary technologies • protection of innovation from imitation • high entry barriers for component suppliers • craftsmanship

A modular architecture is closely linked to modularity. Baldwin & Clark (1997) describe modularity as a strategy of "building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole." Modularity also increases the flexibility in the allocation of manufacturing task, which in turn helps the use of postponement strategies (van Hoek & Weken 1998). Modularity has become a trend in many industries, including computer and automotive industry (Ro et al. 2007; Baldwin & Clark 1997). Ro et al. (2007) investigate modularity in US automotive industry and found that benefits of modularity include time and cost reductions and increasing flexibility. However, modularity also impact on the role of the first-tier suppliers as modular product requires first-tier suppliers to deliver complete modules rather than individual components. Thus, modular strategy leads to a transfer of higher percentage of value-added activity from original equipment manufacturer (OEM) to first-tier supplier. (Doran 2004.) For an OEM it may impose a risk, as the quality and even the appeal of the vehicle depends both module suppliers and OEM. Moreover, there is a good deal of proprietary intellectual property that must be protected when supplier design core parts. (Ro et al. 2007.) Due to modularity, also the power of suppliers may increase (Cox 1999; Fine 1998, p. 8-9)

Product modularity is also related to product variety that the company can develop and produce (Pero et al. 2010). Ulrich (1995) defines product variety as "the diversity of products that a production system provides to the marketplace". Variation can be in terms of product's functional elements, or in terms of product's performance relative to a functional element (Ulrich 1995). There are clear interdependences between variation and the supply chain management. From the firm's perspective, a trade-off exists between product variety and operational performance, which includes performance of its internal operations, as well as its component sourcing performance. (Salvador et al. 2002). De Groote (1994) states that an increase in the product variety induces a firm to invest in process flexibility. However, in many situations it is not possible to tell which of the process flexibility or product variety comes first. Also commonality refers to variation as it is a measure of the degree to which product variants share the resources and assets (Huang et al. 2005).

Also decisions on serviceability, maintainability and support must be done during concept development. Asiedu & Gu (1998) argue that there are actually three coordinated life cycles that need to be considered. They are product life cycle, process life cycle and support life cycle. Product life cycle includes the design development, production, use and disposal whereas the process life cycle includes manufacturing system design, manufacturing operations and recycling process. The last one, the logistics support life cycle includes support system design, support and maintenance, as well as recycling support.

2.2.2. Supply chain design decisions

Supply chain design decisions include supplier selection as well as production and distribution system design issues. Important decisions include: Which components will be designed specifically for the product? Who will design and produce the product? What is the configuration of the physical supply chain? What type of process will be used to assemble the product? Who will develop and supply the process equipment? (Krishnan & Ulrich 2001.)

Nowadays most companies design and make only a portion of what constitutes their products, buying the rest from a complex multi-link chain of suppliers (Fine & Whitney 1996). The different alternatives range from performing both design and production internally, performing own design and contracting with suppliers the production, to contracting with suppliers to take care of both design and production based on company's specifications (Ulrich & Ellison 2005). The decision about what to do in house and what to outsource is often called *make-buy* decision. As Ulrich & Ellison (2005) state, potential conflicts arise when there is a high requirement to integrate design and production, but a strong motive to outsource one of them and internalize the other. The decision making process of make-buy decisions begins already at the high organizational levels, where strategic core competencies in product and process design and manufacture are assessed. The object of the strategic process is to clarify the requirements for success in current and future new products and future technological needs. Moreover, the company should have an idea about the specific roles and responsibilities it wishes to place on suppliers that will be selected. Whereas, the role of product development team is to formally specify these objectives in as much detail as possible. (Handfield et al. 1999.)

Another supply chain design decision regards whether the firm chooses to design new components, or to select components from suppliers' catalogs, or from those already in use in the company. The decision can be called as *design-select* decision. The advantages of selecting an existing component include minimizing investment, exploiting economies of scale, and maintaining organizational focus. On the other hand, designing product-specific components allows a firm to maximize product performance with respect to customer requirements, minimize the size or mass of a product; and minimize the true variable costs of production. (Ulrich & Ellison 1999.)

Maybe one of the most important supply chain design decisions is the supplier selection. In the literature there are numerous decisions methods for supplier selection (see Weber et al. 1991; Holt 1998; Degraeve et al. 2000; de Boer et al. 2001). However, there are differences between first time buys, modified rebuys and straight rebuys (Faris et al. 1967; de Boer et al. 2001). Furthermore, the complexity of supplier selection may differ across the profit impact and supply risk. Kraljic (1983) classifies purchasing situations based on these factors into four class; *routine items, bottleneck items, leverage items,* and *strategic items*.

When choosing suppliers, the project team must not only understand the supplier's ability to meet cost, quality, and ramp-up goals, but also assess supplier's technology roadmap, their level of design expertise, and the volatility of change within the particular technology being integrated (Handfield et al. 1999). Hoetker (2005) suggest that differences in both technical capabilities of suppliers and in their relationships with the buyer affect the calculus of supplier selection. Based on studies about notebook computer manufacturers' sourcing decisions he proposes a framework in which the value of past transactions depends on the technological uncertainty posed by the desired innovation. The connection is represented in figure 2.6.

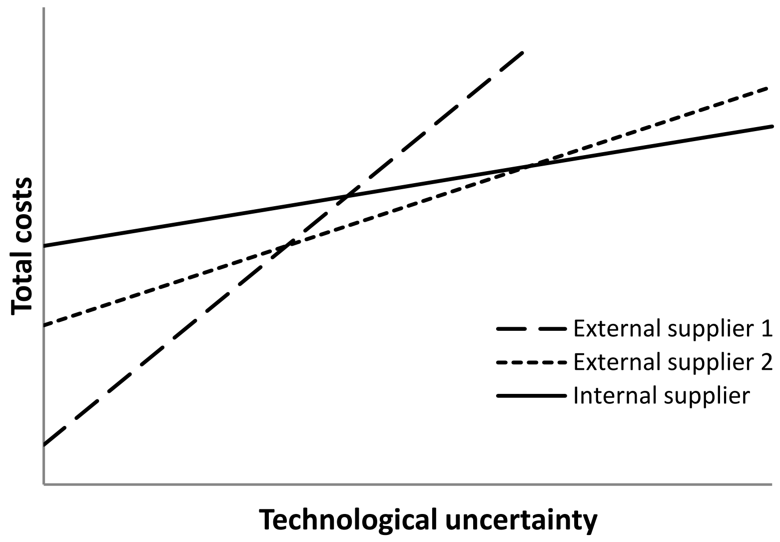

Figure 2.6. *The impact of differing technical capabilities and buyer-supplier relationships (Hoetker 2005).*

In figure 2.6., the external supplier 2 has superior technical capabilities, but external supplier 1 has transacted with the buyer significantly more than supplier 2 has. Thanks to earlier collaboration, supplier 1's costs increase more slowly with increasing uncertainty than do supplier 2's. At extreme levels of uncertainty, the value of internal supply relationships becomes very high and past relationships lose their significance. The framework bases on an assumption that at low levels of uncertainty there are few communication or governance cost and the total cost consists mainly of production costs. As uncertainty increases, communication and governance costs form an increasing part of the total costs. Handfield et al. (1999) further gathered elements that are likely to be important in considering new or existing supplier for integration:

- Targets – Is the supplier capable to hit targets regarding cost, quality, and product performance/function?
- Timing – Will the supplier be able to meet the product development schedule?
- Ramp-up – Will the supplier be able to increase capacity and production to meet volume requirements?
- Innovation and technical – Does the supplier have the required expertise and facilities to develop and manufacture the product, and solve problems when they occur?
- Training- Do the supplier's key personnel have the required training?

The elements were gathered within a study in which several industrial groups were included. Furthermore, Christopher (2011) note that if the supply chain design decisions involve unreliable supply sources this could potentially increase the chance of supply chain disruption. Again, choice of the supplier can impact replenishment lead time, especially when the supply source is offshore.

2.2.3. Product design decisions

Krishnan & Ulrich (2001) use the term *product design* to refer to the detailed design phase, which consists of the specification of design parameters, the determination of assembly relations, and the detail design of the components including material and process selection.

High levels of part complexity have been found to require complex manufacturing processes which result higher production costs (Banker et al. 1990). Rodriguez-Toro et al. (2003) divide complexity into two levels: component and assembly complexity. Component complexity includes those aspects of the product design that relates to components. These are manufacturing complexity and process complexity. Manufacturing complexity includes the type, number and difficulty of manufacturing operations and process complexity relates to difficulties associated with alignment, insertion and handling operations on individual parts or subassemblies. On the contrary, assembly complexity incorporates those aspects of a design that affect the efficiency of the assembly sequence. These are structural complexity and sequence complexity. The structural complexity relates to the product structure and thus to the ease of assembly and the critical assembly path, while the sequence complexity relates to the number of operations required to assemble the product and the assembly sequence. As Banker et al. (1990) state, a large proportion of the costs is determined during the design phase especially in manufacturing environments, where product complexity greatly influences the final costs of the product. Thus, the designers should be informed of the cost effects of different design alternatives. Without the information, designers tend to add more features and design more complex products.

Component commonality refers to the use of same version of a component across multiple products (Fisher et al. 1999). Low levels of component commonality will add complexity (Christopher 2011, p. 166). Component part commonality has found to have a significant effect on system performance. For instance, company standardization programs that increase the degree of component part commonality result in manufacturing cost reductions (Collier 1981).

Material selection is one of the most important activities for a product development process (Sapuan 2001). It is also an important part of total design model introduced by Pugh (1990). The proportion of material costs varies across industries. For example, in mechanical and civil engineering, material costs often exceed 50% of the product cost and the material volume is very large (Ashby 1989). The material selection process includes choosing the best material for the particular design and it is included in every stage in total design process (Sapuan 2001). Constraints in material selection are usually resulting from non-negotiable characteristics of the products: the temperature and the environment it is used, the weight, the costs and so on (Ashby 1989). Also the environmental issues are getting more and more attention in material selection (Kaiser et al. 2001). The economics of recycling can be enhanced by using compatible materials as well as easily separable joints and providing easy access for power tools (Chen et al. 1994).

2.2.4. Production ramp-up and launch decisions

Production ramp-up and launch decisions include decisions about how the production ramp-up is supposed to do, the sequence in which products are introduced in different markets, how much test marketing is needed and so on (Krishnan & Ulrich 2001).

Ramp-up is the process of increasing production rate of a factory from the first lot to full volume, when a new product is introduced into a factory (Haller et al. 2003). Butler et al. (2006) study the planning of supply chain for new products. They state that for a new product launch, the company must trade off the potential benefits of fully meet demand forecasts and the disadvantage of high initial investment. The statement focuses on two main ideas; the company needs to stay financially viable during the product development, and second, there are many potential growth scenarios for the new product.

2.2.5. Decision framework for NPD and SCM alignment

Based on the above literature review many supply chain issues will be determined during the product development process. The issues are further collected in the framework illustrated in figure 2.7. The framework portrays the issues that should be taken into account during the product development process in order to affect the resulting supply chain and firm's performance.

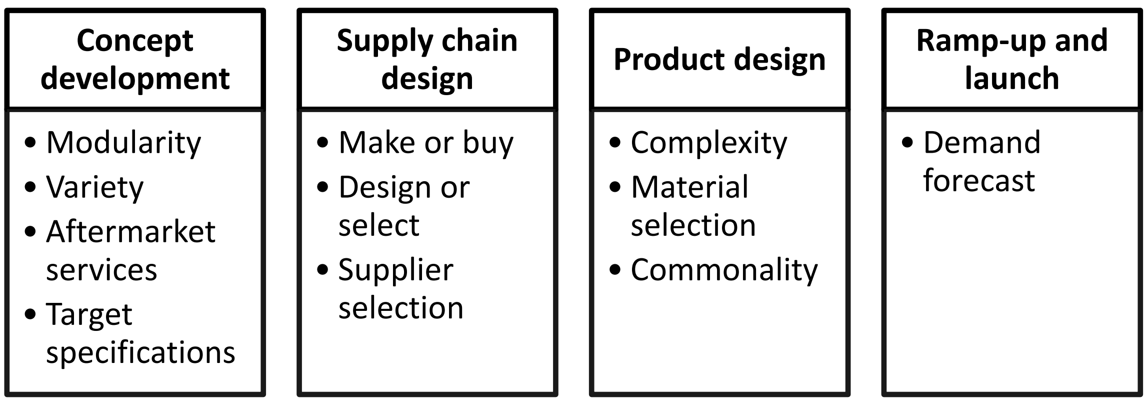

Figure 2.7. *Decision framework for NPD and SCM alignment.*

However, there is no mention in the literature how these decisions should be made and what issues should be taken account when making the decisions. Furthermore there is no mention under whose responsibility these issues are.

2.3. Requirements and challenges for successful decisions

As mentioned in chapter 2.1.3, the target of NPD and SCM alignment is to secure that the developed products can be delivered at the targeted cost, time and quality (Pero et al. 2010). Consequently, a requirement for the new product development decisions is that they contribute to the formation of an effective and strategically suitable supply chain. Also the globalization generates new challenges for the supply chain management and thus to new product development decisions. The main object of this chapter is to study what issues should be taken account when making the NPD decisions in order to achieve as suitable as possible supply chain in global environment.

2.3.1. Supply chain performance measures

The vast majority of the literature on supply chain performance measures can be classified as operational, design or strategic (Huang et al. 2004; Shepherd & Günter 2006). The operational category includes the daily operations of a facility (Huang et al. 2004), whereas the design category focuses on the optimization of the performance through redesigning the supply chain (Shepherd & Günter 2006). The strategic decisions on the contrary require a broad understanding of the dynamics of the supply chain and the development of objectives for the whole chain (Gopal 1992). Furthermore, the task includes evaluation of alternative supply chain configurations and partnerships, as well as the evaluation of the opportunities that can increase firm's competitive capabilities (Huang et al. 2004). As the main research question suggests, in this thesis the focus is on strategic performance measures.

Beamon (1999) studies different supply chain performance measures and argues that the use of cost as a primary measure is inadequate to measure total supply chain performance. Furthermore, most performance measures lack the connection with firm's strategy. Use of such inadequate measures can lead inconsistencies with the strategic goals of an organization and inability to adapt to future changes. Based on these arguments, she introduces three types of performance measures that should be incorporated into supply chain measurement system. They are flexibility, resources, and output. The *flexibility* relates to the ability to respond to a changing environment, *resources* to the high level of efficiency, and *output* to the high level of customer service. Also Huang et al. (2004) are of like mind on that issue, as they state that based on their survey, the most promising model for supply chain strategic decision making is the supply chain operations reference (SCOR) model. The guiding principle of the model is that a balanced approach is crucial; single indicators (e.g. cost or time) are not adequate to measure supply chain performance, which must be measured at multiple levels. The performance metrics in the model include reliability, flexibility, responsiveness, cost and efficiency. (Shepherd & Günter 2006.)

Johansson et al. (1993) express the value delivery of a business in terms of a simple equation:

$$Total\ value\ = \frac{Quality \times Service\ level}{Costs \times Lead\ time}$$

Likewise, the cost is not the only performance measure in the model. As Christopher & Towill (2000) and Mason-Jones et al. (2000) point out, the merit of the equation is that it highlights the futility of improving one performance measure at the expense of worsening another.

Based on these results it can be conclude, that the product development decisions affecting supply chain can't be made based on the costs only; also the other indicators must be taken account.

2.3.2. Supply chain strategies

In the literature two different supply chain paradigms are generally distinguished: lean and agile. According to Naylor et al. (1999) "Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place". Leanness, on the other hand, "means developing a value stream to eliminate all waste, including time, and to ensure a level schedule." Lean thinking is usually associated with car manufacturers and especially with Toyota, for the term is often used in the same context as lean manufacturing (Womack et al. 1990) and the origin of lean manufacturing is in Toyota Production System (Ohno 1988). Table 2.2. illustrates the differences between lean and agile supply chain strategies.

Table 2.2. *Comparison of lean and agile supply chain (Mason-Jones et al. 2000).*

Distinguishing attributes	*Lean supply*	*Agile supply*
Typical products	Commodities	Fashion goods
Marketplace demand	Predictable	Volatile
Product variety	Low	High
Product life cycle	Long	Short
Customer drivers	Cost	Availability
Profit margin	Low	High
Dominant costs	Physical costs	Marketability costs
Stockout penalties	Long term contractual	Immediate and volatile
Purchasing policy	Buy goods	Assign capacity
Information enrichment	Highly desirable	Obligatory
Forecasting mechanism	Algorithmic	Consultative

However, the issue is not “lean vs. agile”, but the selection and integration of appropriate aspects of these paradigms appropriate to the particular supply chain strategy (Christopher & Towill 2002). Both of the paradigms have their benefits and the combination of lean and agile paradigm is called leagility. The idea of leagility is to position the de-coupling point so that the supply chain can respond to a volatile demand downstream yet providing level scheduling upstream (Naylor et al. 1999). As Christopher (2000) state, the challenge to supply chain management is to develop lean strategies up to the de-coupling point, but agile strategies beyond that point. In addition, strategic stock is usually held at the decoupling point as buffer between customer orders and production output. That is a critical matter for consideration when deciding when to adopt agile or lean manufacturing techniques. (Naylor et al. 1999.) The situation is illustrated in figure 2.8, in which the decoupling point or the strategic stock is marked with triangle.

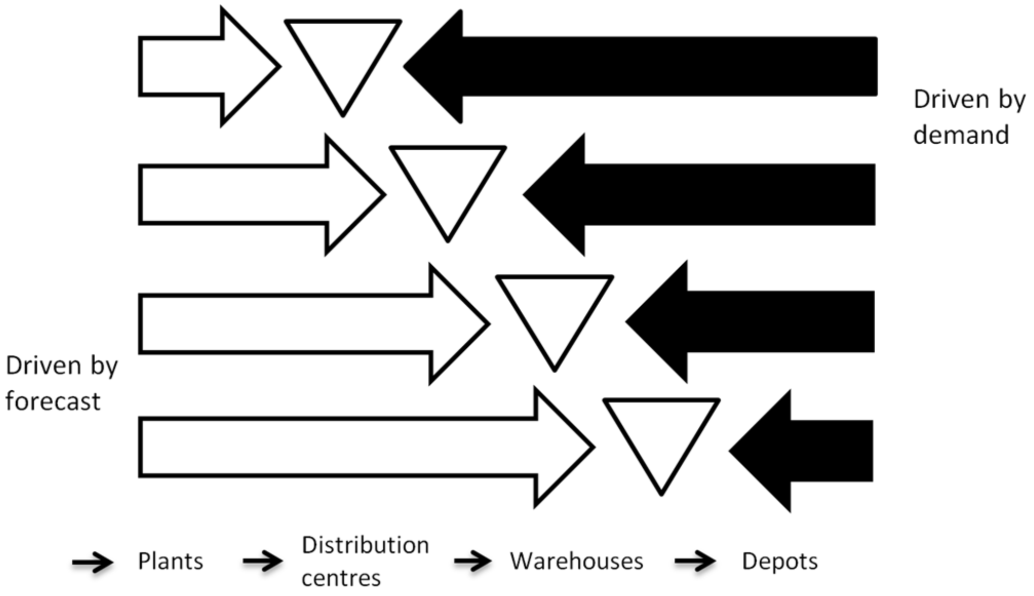

Figure 2.8. *De-coupling points and strategic inventory (Christopher 2000).*

Associated with the positioning of the decoupling point is the postponement strategy. Postponement, or in other words, postponed manufacturing (van Hoek 1998), delayed configuration or late customization, is based on a principle, where product are designed using common platforms, components, or modules, but the final assembly or customizations does not take place until the final market destination and/or customer requirement is known (Christopher 2000). By applying postponed principles, generic modules of products can be manufactured in large-scale operations, whereas the final manufacturing or assembly can be performed near the final customer (Feitzinger & Lee 1997). Van Hoek (1998) state that postponement may contribute to both localization and globalization. Postponement can foster localization by enhancing local responsiveness in adaptation product to local markets and in customization products based on customer orders. At the same time, postponed manufacturing can contribute to globalization by enhancing global efficiency in manufacturing of generic modules in global manufacturing centers. The ability to customize products locally means that it is possible to offer a higher level of variety at a lower total cost and at the same time pursue strategies of “mass customization” (Christopher 2000).

A number of frameworks and classifications have been proposed in the literature to guide the choice of supply chain strategy. Based on them, it can be argued that sourcing strategy, operation strategy and route-to market need to be suitable to specific product or market conditions (Christopher et al. 2006). One of the earliest classifications was proposed by Fisher (1997), who suggests the first step in devising an effective supply chain strategy is to consider the nature of the demand for the products. He concludes that functional products need efficient supply chains, whereas innovative products need responsive supply chains. Their framework is presented in figure 2.9.

	Functional products	**Innovative products**
Efficient supply chain	match	mismatch
Responsive supply chain	mismatch	match

Figure 2.9. *Matching supply chain with products (Fisher 1997).*

Lee (2002) proposes that the “uncertainty framework” is a simple but powerful way to select the right supply chain strategy. The framework expands Fisher’s (1997) framework to include supply uncertainties. Also Vonderembse et al. (2006) study the relationship between different supply chain types and different product types. They take additionally product life cycle into account when matching supply chain strategy with the product. Furthermore, Christopher & Towill (2002) suggest a three dimensional classification appropriate for global supply chains, but their variables are product type (either standard or special), demand (either stable or volatile) and lead time (either short or long). Christopher et al. (2006) further developed a framework of selecting pipeline strategy based on product demand and supply characteristics. The framework is presented in figure 2.10.

Supply	**Long lead time**	<u>Lean</u> Plan and execute	<u>Leagile</u> Postponement
	Short lead time	<u>Lean</u> Continuous replenishment	<u>Agile</u> Quick response
		Predictable	**Unpredictable**
		Demand	

Figure 2.10. *Selection of pipeline strategy (Christopher et al. 2006).*

On the horizontal axis of the figure, the demand characteristics are shown in terms of predictability, which is likely to be determined by the variability of demand. The vertical axis on the other hand reflects the replenishment lead times. If the time to respond to the increased demand is measured in months rather than days then the product could be regarded as product with long lead time. (Christopher et al. 2006.)

A further factor to influence the choice of supply chain strategy is the market winning criterion (Christopher & Towill 2000). If the cost is the primary market winner, then the focus should be on efficiency and thus on lean strategy. But if the availability or service level is the market winner, then the focus should be on agile strategies. (Mason-Jones et al. 2000.) The idea is illustrated in figure 2.11. However, according to Christopher & Towill (2000), the reality usually is that lean strategies are suitable only in situations where demand is stable and products are standard.

	Market qualifiers	Market Winners
Agile supply	Quality Cost Lead time	Service level
Lean supply	Quality Lead time Service level	Cost

Figure 2.11. *Market winners and market qualifiers for agile and lean supply (Mason-Jones et al. 2000).*

To summarize, different variables and their gradation affecting the selection of supply chain strategy are gathered and presented in table 2.3. Based on the literature, it is quite obvious that the supply chain must be aligned with the product characteristics, demand and customer preferences. Furthermore, one must take account the supply uncertainty and lead times. As Christopher et al. (2006) state with the Sony example, for many commodity items the lower manufacturing cost may well outweigh the higher cost of transport and the longer lead times. However, for other categories of products, this may not be true. It is also worth of note, that the products may require different kinds of supply chains based on their stage in product life cycle. As Butler et al. (2006) state, the demand for new product has significant degrees of uncertainty, and moreover, the demand will differ through product life cycle. As said, one common mistake is that the supply chain is designed for the forecasted demand of the mature market and the demand is assumed to be constant (Lee and Billington 1993; Rao et al. 2000).

Table 2.3. *The variables to take into account when selecting supply chain strategies - summary of the literature.*

Variable	**Gradation**	**Author**
Product type	functional, innovative standard, innovative, hybrid standard, special	Fisher 1997 Vonderembse et al. 2006 Christopher & Towill 2002
Product life cycle	introduction, growth, maturity, decline	Vonderembse et al. 2006
Demand	volatile, stable predictable, unpredictable	Christopher & Towill 2002 Christopher et al. 2006
Demand uncertainty	low, high	Lee 2002
Supply lead time	short, long	Christopher & Towill 2002 Christopher et al. 2006
Supply uncertainty	low, high	Lee 2002
Market qualifiers and market winners	quality, cost, lead time, service level	Mason-Jones et al. 2000

If the notation that large part of the supply chain is determined during the new product development process is taken account, it is evident that there should be a clear idea of the desired supply chain strategy before the new product development starts. Furthermore, there should be a constant comparison between the characteristics of the new product and the upcoming supply chain during the new product development process. To make the task even harder, also the whole product life cycle should be taken into consideration when making the supply chain decisions.

2.3.3. Challenges of global supply chain

Due to globalization the interdependency among economies worldwide has increased. The attraction of cost-savings has led to the mass-migration of manufacturing from developed world to emergent economies (Warburton & Stratton 2002; Christopher et al. 2006). Companies are now facing issues with global sourcing including unreliable delivery, longer lead times, and poor quality (Butner 2010). These issues pose further challenges for the decision making during the new product development process.

One problem with the offshore manufacturing is that the concept of cost has been understood very narrowly for the cost criteria used has been the unit cost of manufacture or purchase. Thus, the costs related to the wider concept of supply chain are often ignored; the unit cost does not take into account the additional inventory, the increased risk or the decreased agility. (Christopher & Towill 2002.) Furthermore, the lead times also lengthen due to distance and complications in coordinating shipments from far-off suppliers, through forwarders, shippers, customs, and delivery networks (Christopher et al. 2006). As a consequence, the true supply chain costs should also include such elements as inventory carrying costs, cost of markdowns, costs of lost sales, transaction costs, transportation, warehousing and duties. Even though the findings result from a survey of retailers, the authors state that the experiences are not different to electronics or high technology companies in general. (Christopher & Towill 2002.) Furthermore, the global sourcing requires the ability to manage different cultural, legal and regulatory environments (Christopher et al. 2006).

The globalization and the interdependence of the greater supply chain have also elevated risks and made them more difficult to control (Butner 2010). Manuj & Mentzer (2008) divide risks in global supply chain in four types. They are supply risks, demand risks, operational risks and other risks. Figure 2.12. shows the interaction between different types of risks together with risk examples. Supply, operational and demand risks affect each other and are linked to the context, in which other risks can occur. No one in the supply chain have direct control over the other risks. It is also important to note, that an outcome for one firm can be a risk to another firm.

Figure 2.12. *Risks in global supply chains (Manuj & Mentzer 2008).*

Furthermore, Manuj & Metzer (2008) notice that in global supply chains risks are linked to each other with complex patterns so one risk may easily lead to another. The phenomenon is present also in domestic markets, but its consequences are bigger and more unpredictable in global supply chains. Also Barry (2004) highlights the risks associated to global supply chains. He bring out the risks related to supply sources, intellectual properties, skilled labor force, fuel prices, political situations, and non-compatible technologies.

2.3.4. Conceptual framework for decision making

Figure 2.13. shows the conceptual framework for the decision making during the new product development process. The framework highlights the issues that should be taken account during the NPD project. First of all, there should be a target for supply chain strategy before the project starts and strategy should be aligned with the product type. Important issues to consider are the expected demand for the product during its whole life cycle and the customer preferences. When the preliminary objects are set, the NPD decisions can be made to better fit the company's overall strategy, which in turn could improve company's performance.

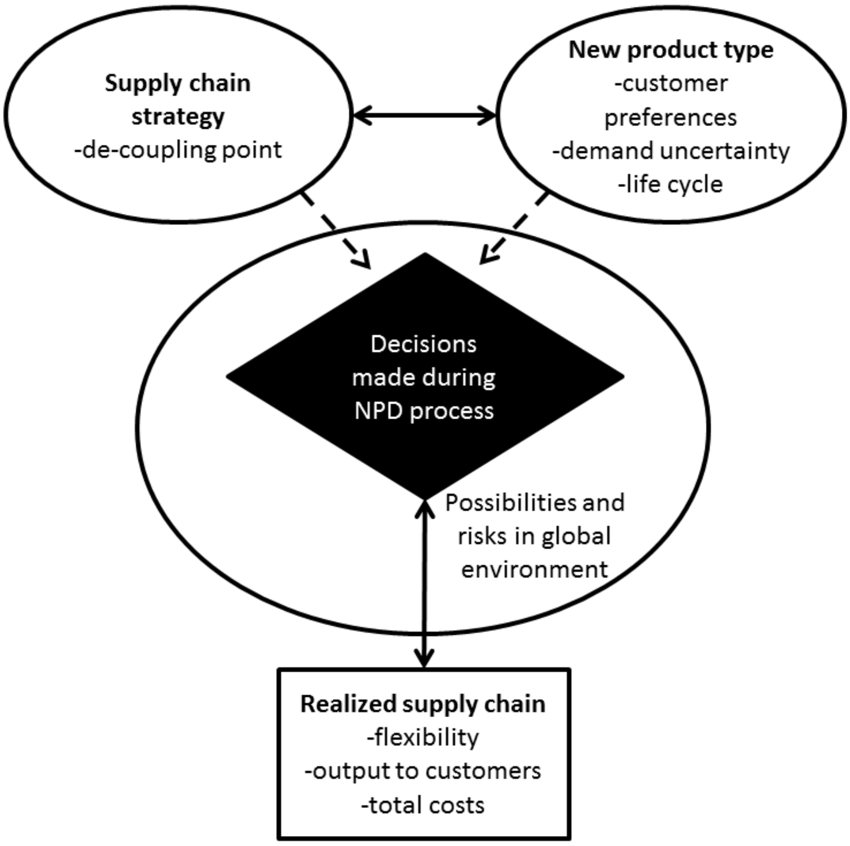

Figure 2.13. *Conceptual framework for decision making during the NPD project.*

During the NPD project the possibilities and risks in global environment naturally affect the decisions. The company cannot make any decisions out of the context. Based on the initial targets and the possibilities the company should make the decisions so that they lead to as suitable as possible supply chain. The supply chain can be measured based on its flexibility, output to customers and total costs. However, the decision making process is not linear. There should be constant evaluation on how NPD decisions affect supply chain and vice versa.

2.4. Improving NPD decisions

In order to improve the success of new product development scholars have demonstrate different ways to integrate internal functions and linking them with external suppliers. These concepts could also improve the alignment of new product development and supply chain management. Especially, these concepts could offer insights on how product development decisions are made and how different issues affecting alignment can be better taken account.

2.4.1. DFX and concurrent engineering

In 1960s many companies developed manufacturing guidelines for use during product design. The idea was that manufacturing data were gathered together and after that designers could acquire the manufacturing knowledge for efficient and effective design. However, the main focus was on design of individual parts for producibility, not on manufacturing and assembly processes. (Kuo et al. 2001). Accordingly, when methods for analyzing assembly difficulties were developed in the 1970s it was found that there was a conflict between producibility and assembly (Boothroyd et al. 2001). As a consequence, design for manufacture and design for assembly were introduced. Design for manufacture (DFM) refers to "the design for ease of manufacture of the collection of parts that will form the product after assembly" (Boothroyd et al. 2001). The focus of DFM is he interdependency of component design and component productions (Ulrich & Eppinger 2008). When production process is stable and well understood, it is possible to set design rules that express the constraints of the production process (Adler 1995). However, when the production process is new, poorly understood or unusual the component design must be made iteratively with the production process (Ulrich & Ellison 2005). Design for assembly (DFA) refers to "the design of the product for ease of assembly". Accordingly, design for manufacture and assembly (DFMA) is a combination of DFA and DFM. (Boothroyd et al. 2001)

In figure 2.14., the scope of DFA and DFM is presented in the context of the design for life cycle or life cycle engineering. Life cycle engineering goes beyond the life of the product itself and simultaneously considers the issues of the manufacturing process and product service systems (Asiedu & Gu 1998). However, there is some overlap between different "design for" activities (Keys 1990). As a result, Gatenby (1988) generalized all the related design methodologies under the more general heading of design for X (DFX).

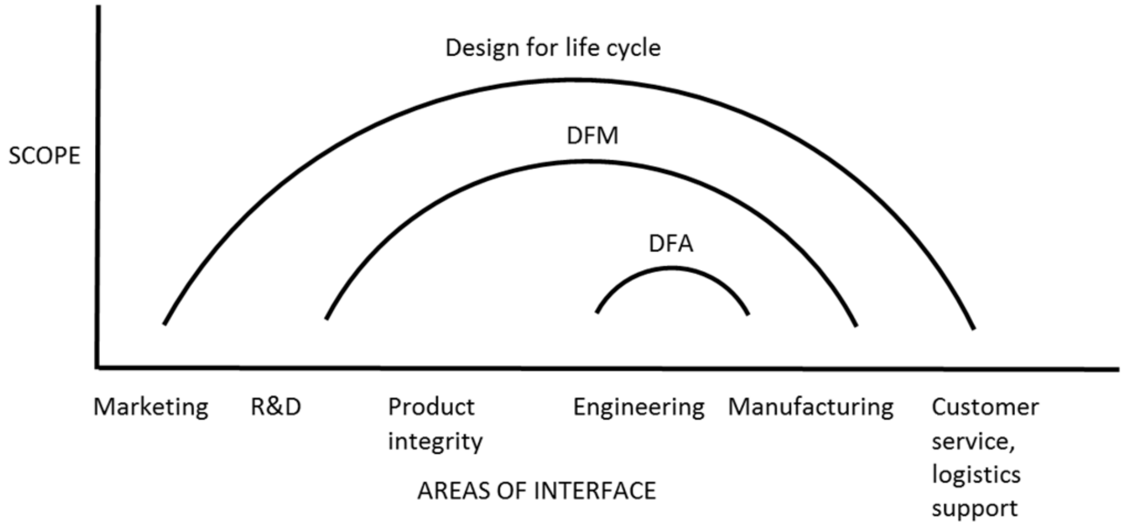

Figure 2.14. *A conceptual relationship of different "design for" activities (Keys 1990).*

Concurrent engineering (CE) is an approach in which the simultaneous design of a product and all its related processes in a manufacturing system are taken account in order to ensure match between product's structural and functional requirements and the associated manufacturing implications (Jo et al. 1993). Concurrent engineering dictates that "product and process decisions are made in parallel as much as possible and that production considerations be incorporated into the early stages of product design" (Fine et al. 2005).

However, the concurrent engineering approach combines only the product design and process decisions, but the concept of supply chain is missing. Thus, the notion of three-dimensional concurrent engineering (3D-CE) was created. It embodies simultaneous and coordinated design of products, manufacturing processes, and supply chains. (Fine 1998.) In other words, 3D concurrent engineering is an improved model of new product development supported by concurrent engineering, in which the traditional focus on an appropriate match between product and process is augmented by an additional consideration of supply chain configuration (Ellram et al. 2007). The model is presented in figure 2.15.

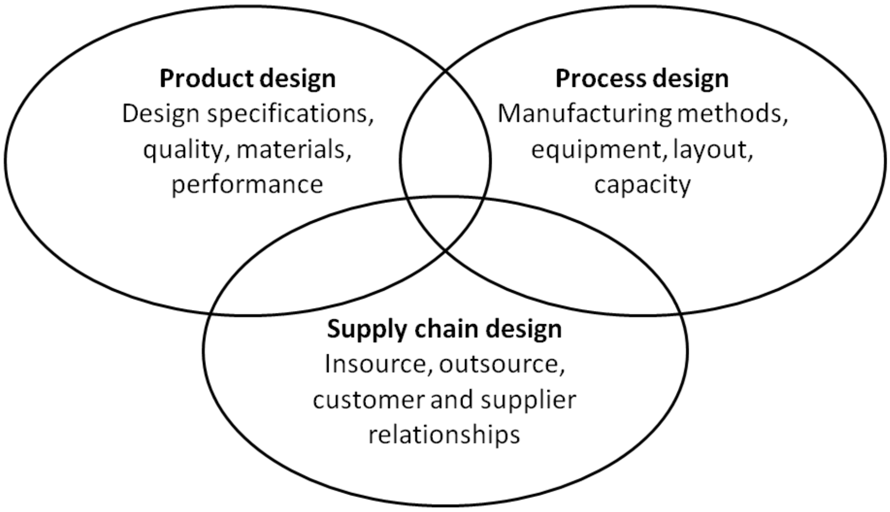

Figure 2.15. *3D concurrent engineering (adapted from Fine 1998 and Ellram et al. 2007).*

Ellram et al. (2007) define *product design* as a process dealing with product's specifications, *process design* as a process focusing on the methods that will be used to manufacture the product and *supply chain design* as a process considering in-sourcing and outsourcing, logistical channels, suppliers and customers, and the type of relationships an organization has with other members of the supply chain.

2.4.2. Target-costing and value engineering

Target-costing is an integral process in the larger process of new product development (Ellram 2000) and its aim is to support the cost reduction process in developing new products (Monden & Hamada 1991). Ellram (2000) studied purchasing and supply chain management's participation in the target costing process and she state that involvement in target costing represents a very positive way for purchasing and supply chain management to contribute to organizational success and to be involved early on product development.

Ansari & Bell (1997, p. 11) define target costing process as "a system of profit planning and cost management that is price led, customer focused, design centered, and cross functional". It "initiates cost management at the earliest stages of product development and applies it throughout the product life cycle by actively involving the entire value chain". Ellram (2000) divides target costing process into six steps. The first step in target costing for new products is to identify a need in the market and identify a product characteristic that will fulfill it. The second step is to establish target selling price. The selling price must be acceptable to customers and capable of withstanding competition (Ansari & Bell 1997). Step three involves setting the target profit and establishing the target cost. In step four, costs are broken down hierarchically. First, the costs are allocated among the internal operating cost centers. The costs of external purchases are further broken down into individual component and material level. Step five is the hardest one and it takes most time and resources. During this step, the organization works with suppliers to achieve the target cost. When the target cost has been achieved the sixth step can be carried out. The step includes new product rollout, target cost monitoring, and continuous improvement efforts. (Ellram 2000.) On the contrary, Cooper & Slagmunder (1997, pp. 74-75) divide target costing process into market-driven costing, product-level target costing and component-level target costing. Market-driven costing aligns the marketplace in to the new product development process and it determines the allowable cost. Product-level target costing on the contrary disciplines the creativity of the product design whereas the component-level target costing disciplines and focuses the creativity of the supplier in ways that are beneficial to the firm. The sections can be seen in target costing triangle illustrated in figure 2.16.

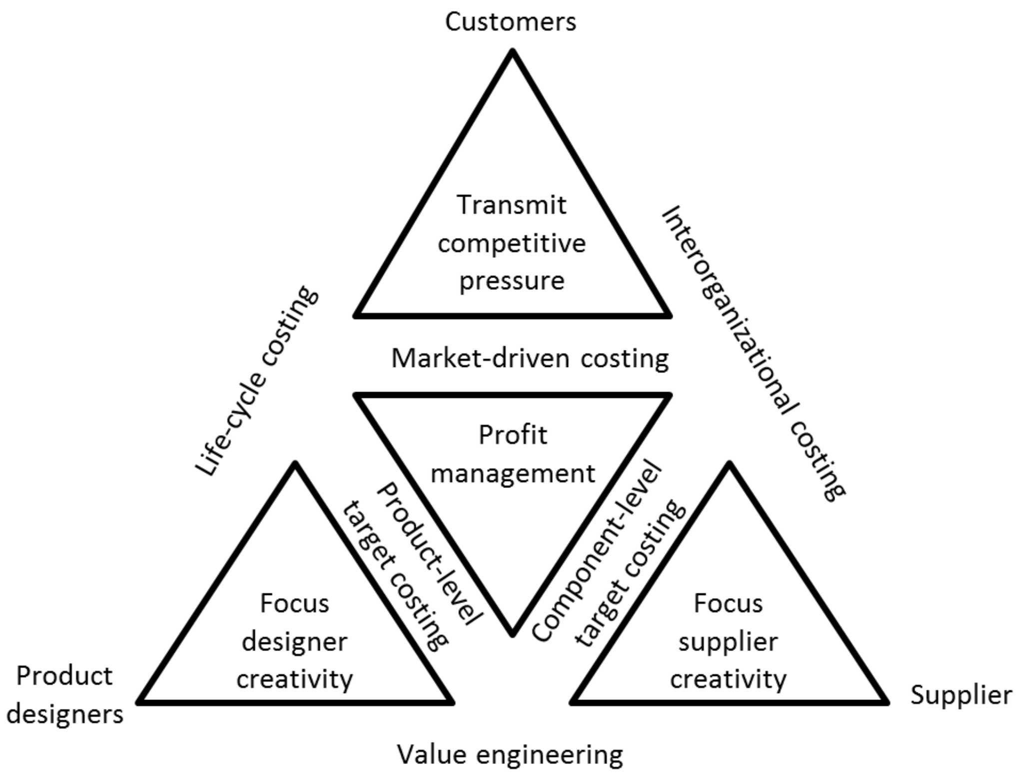

Figure 2.16. *The target costing triangle (Cooper & Slagmunder 1997, p. 108).*

Cooper & Slagmunder (1997, p. 80) define value engineering as a "systematic, interdisciplinary examination of factors affecting the cost of a product with the aim of devising a means to achieve its specified purpose at the required standards of quality and reliability and at an acceptable cost. Most value engineering activities occurs either in the product level or in the component level sections of the target costing process, as can be seen from figure 2.16 (Cooper & Slagmunder 1997, p. 129). Value engineering should be performed as early as possible to maximize the results; the later it is applied, the bigger the required investments are, and the stronger the resistance to changes is (Dell'Isola

1997, p. xxii). When value engineering is integrated with a target costing system, its objective is to increase the functionality of products but at the same time maintain their target cost (Cooper & Slagmunder 1997, p. 137).

2.4.3. Supplier integration

Studies regarding a wide range of industry groups indicate that there is a positive correlation between supplier integration and new product development project success (Handfield et al. 1999; Petersen et al. 2005). Successful supplier integration involves a large number of variables. Questions that arise include tier structure, degree of responsibility for design, specific responsibilities in the requirement setting process, when to involve suppliers in the process, inter-company communication, intellectual property agreements, supplier membership on the project team, and alignment of organizational objectives with regard to outcomes. (Handfield et al. 1999.) Petersen et al. (2005) emphasize the criticality of the supplier selection regardless of the stage at which suppliers are integrated, and regardless of the level of supplier's responsibility in the project. They state that when selecting suppliers one must consider not only the capabilities of the supplier, but also the culture of the supplier, which will affect the interaction possibilities between the companies. The decision to integrate suppliers derives usually from target costing, lack of internal design capability or the need to develop a non-core technology (Handfield et al. 1999).

One way to analyze the level of supplier integration in product development is to classify suppliers into four different classes: no involvement, white box, gray box and black box approach (Petersen et al. 2005). The white box approach includes discussions about specifications and requirement between buyer and supplier but the buying company makes all design and specification decisions. With a gray-box approach the supplier and the customer enter into an informal, or sometimes a formal joint development effort, which may include information and technology sharing and joint decision making regarding design specifications (Petersen et al. 2005). The supplier provides expertise, suggestions and other input towards the product development but typically is not solely responsible for developing parts, let alone modules for the final product (Koufteros et al. 2007). On the other hand, a black-box approach implies that the supplier is informed of customer requirements and is given almost complete responsibility for the purchased item (Petersen et al. 2005). The classification is illustrated in figure 2.17.

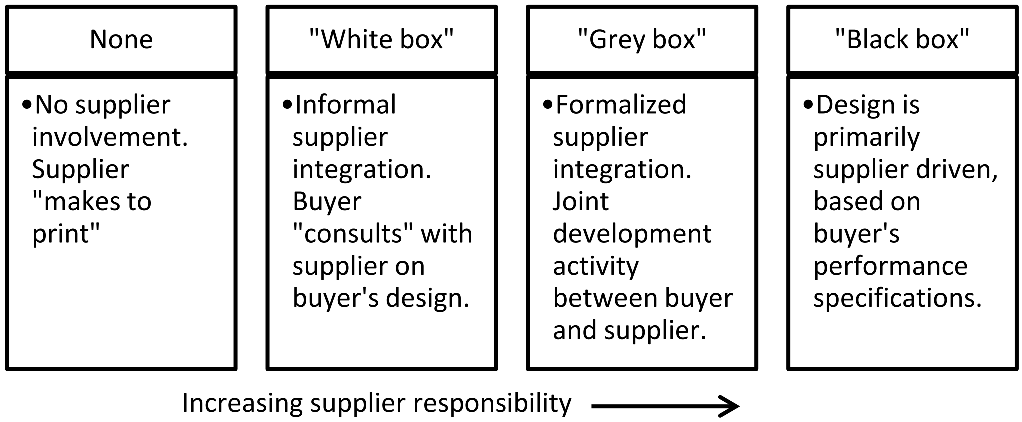

Figure 2.17. *Spectrum of supplier integration (Petersen et al. 2005).*

Petersen et al. (2005) state that in the case of black box integration, supplier input on technical objectives has a significant impact on project team effectiveness. However, involving the supplier in setting business metrics and targets for the project had a positive impact on decision making effectiveness only in the grey box integration, surprisingly not in the case of black box integration.

Furthermore, the stage when the supplier integration occurs differs. There are two factors that should be considered in deciding when to integrate the supplier into product development process. They are the rate of change of the technology and the level of supplier expertise in the given technology. If the technology is uncertain, the integration should be delayed. On the other hand, if supplier's design expertise is significant, they should be integrated early in the process. It has been found in field studies that also the type of the supplier affects the likely integration stage. (Handfield et al. 1999.) Different supplier types and the product development process stages are illustrated in figure 2.18.

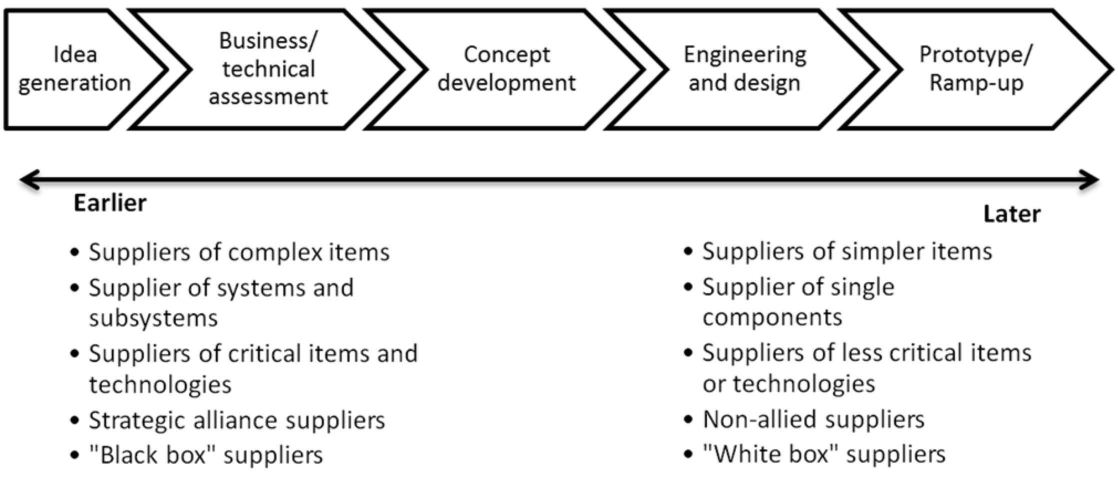

Figure 2.18. *Supplier integration at different stages (Handfield et al. 1999).*

For instance, suppliers of critical nonstandard items are integrated much earlier than suppliers of noncritical standard items. Also the communication is different between the supplier and engineers in these two different cases. In the first case suppliers are involved in face-to-face discussions with engineers on a regular basis whereas in the latter case the communication occurs in the form of computerizations. (Handfield et al. 1999.)

2.4.4. Knowledge sharing between different actors

Hong et al. (2004) state that product development capabilities are derived from firm's ability to create, distribute and utilize knowledge throughout the product development process. Also Desbarats (1999) state that innovation process can be seen as a knowledge supply chain, whose efficiency is measured by the degree to which a vision of the target experience reaches each link in the chain. As Ward (2007, p. 18) states, almost all failed projects result from not having the right knowledge in the right place at the right time. As a consequence, usable knowledge is the basic value that product development team must create during the project.

Hong et al. (2004) suggest that shared knowledge of customers, suppliers, and internal capabilities positively affect product development process performance, as well as indirectly affect product development strategic imperatives, as value to customer and time to market. Their model, which was tested using 205 responses on product development projects by US automotive engineers, is presented in figure 2.19.

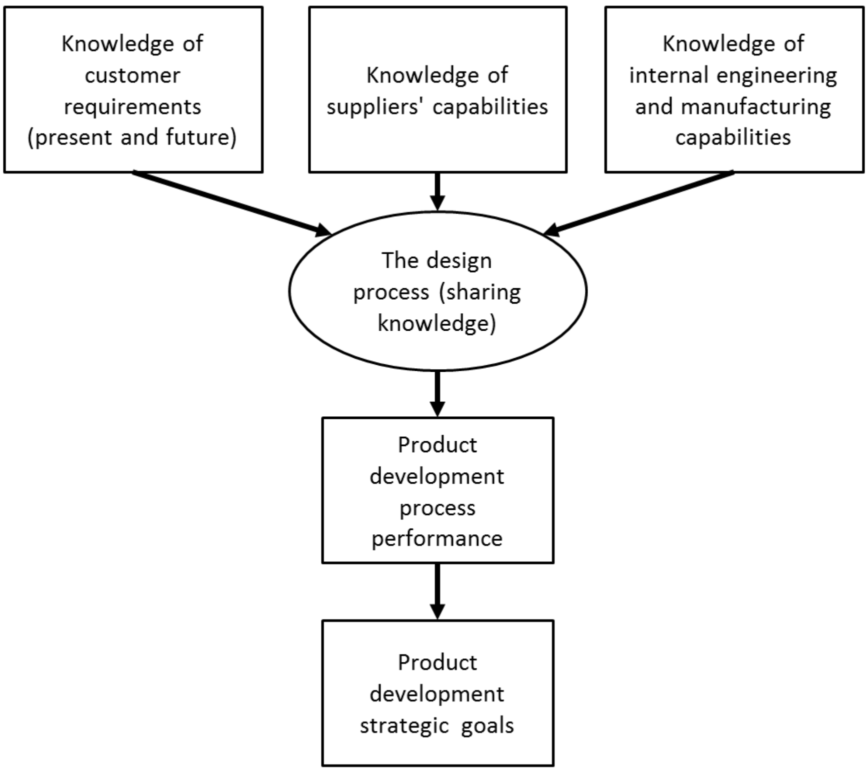

Figure 2.19. *Sharing knowledge during product development process (adapted from Hong et al. 2004).*

According to the model, the knowledge sharing about customer requirements, suppliers' capacities and internal capabilities should occur at concept development stage in new product development process. If the knowledge integration fails or is inadequate, the quality of concept development is questionable; flaws are discovered in later stages and by that time, the majority of costs have already been committed. (Hong et al. 2004.)

Dyer & Nodeoka (2000) studied how Toyota facilitates inter-organizational knowledge transfer within its production network. Their exploratory study suggests that following features play an important role in creating and managing an effective knowledge-sharing network:

1. Creating organizational units that accumulate knowledge
2. Eliminating "proprietary knowledge"
3. Creating multiple knowledge-sharing processes
4. Rewarding knowledge acquisition and application

By creating organizational units that accumulate knowledge Toyota has been able to systematically build stock of knowledge within the network. Furthermore, also suppliers know where to find different type of knowledge, which reduces their search cost. The dilemma of protecting proprietary knowledge but at the same time sharing valuable knowledge is solved by eliminating the notion that there is proprietary knowledge within certain knowledge domains. For example, Toyota creates a norm of reciprocal knowledge sharing by providing free assistance to suppliers and allowing them free access to Toyota's stock of knowledge. Furthermore, Toyota has developed many bilateral and multilateral processes to facilitate the knowledge sharing. Finally, Toyota also monitors all of their suppliers and rewards suppliers that make exceptional knowledge-sharing contributions to the network.

3. RESEARCH METHODOLOGY

3.1. Research strategy

This research was conducted using case study research strategy since the main purpose of the research is to investigate contemporary phenomenon of the alignment of new product development and supply chain management within real-life context. As Yin (2009, p. 4) states, the case study method suits situations, where investigator wants to retain holistic and meaningful characteristics of real-life situation. The method is especially suitable when the boundaries between phenomenon and context are not clearly evident (Yin 2009, p. 18). This is essential as the NPD decisions are strongly related to the decision making context. Furthermore, the case study method suits well this study as the NPD decisions have not been studied previously in SCM context.

In order to avoid uniqueness and artefactual conditions (Yin 2009, p. 61) the research was done using multiple-case design. The benefit of using multiple cases is the possibility to establish whether the findings of the first case occur in other cases as well. This in turn helps to generalize the findings. (Saunders et al. 2009, pp. 146-147.)

3.2. Data collection

Empirical data was collected via semi-structured interviews during autumn 2012. The use of interviews is an important source of evidence when utilizing the case study approach (Yin 2009, pp. 106-108). One pilot interview was conducted to ensure the relevance of the questions. Furthermore, all interviews were recorded to be transcribed afterwards. The questions are illustrated in appendix 1. In order to understand companies' practices more accurately, annual reports and company documentation were also used in data collection.

In total there were three case companies involved in the research and they were selected based on purposive sampling. Purposive sampling allows researcher to select cases that will best enable the researcher to answer the research questions and to meet the research objectives (Saunders et al. 2009, p. 237). All the selected companies operate in Finland. They represent technology intensive manufacturing companies whose products are sold in global markets. To secure the anonymity, the case companies are named as CompA, CompB and CompC. Table 3.1 illustrates the selected companies and the data collection techniques. More detailed information about the characteristics of the companies is provided in chapter 4.1.1.

Table 3.1. *Case companies involved in the research.*

	CompA	CompB	CompC
Industry	mechanical engineering	medical technology	mechanical engineering
Revenue (million €)	> 2 000	< 50	> 500
Product price (€)	100K – 2 000K	100-1000	400K – 1000K
Product life time	> 10 yrs	< 10 yrs	> 10 yrs
Information sources	interviews and company documents	interviews	interviews
No. of interviewees	4	2	3
Avg. duration of interviews	85 min	83 min	71 min

Interviewees from each case company were selected based on snowball sampling. After the first contact, the interviewees were asked to identify desired persons in the case company. From every company two to four persons were interviewed. The number of interviewees depended on the size of the company. However, at least one person working closely with product design or engineering and one person responsible for sourcing or purchasing were interviewed from each company. Besides these, interviewees might include persons involved in productization, production or logistics. In total, 9 persons were interviewed during the research. The interviews took from 49 to 90 minutes while the average duration was 80 minutes. All the interviews were recorded.

3.3. Data analysis

The data from interviews was transcribed by an external service provider. After that, the data was analyzed using the strategy of relying on theoretical propositions (Yin 2009). First, the data were categorized (see Saunders et al. 2009, p. 492). The categories include four decision categories presented in the decision framework in figure 2.7 and four alignment categories identified in chapter 2.4. In addition, data regarding global environment and challenges related to it was compiled to be one category.

After categorization, the results from different companies and different respondents were compared and analyzed. Finally, the results were tried to written up so that they would indicate the original data as well as possible. However, there were some challenges regarding to translation of the quotes since the interviews were made in Finnish and the results represented in the next chapter are written in English.

4. RESULTS

4.1. Supply chain decisions made during the NPD project

In the following section results concerning NPD decisions are discussed based on the decision framework created in chapter 2.2. However, first there is a short introduction to the current NPD processes and supply chains at the case companies.

4.1.1. Case companies' NPD processes and supply chains

New product development process model at CompA is very similar to Cooper's (2008) model described in chapter 2.1. The only difference is that there is no separate testing stage. The process includes five stages and five gates. The stages are called idea management, feasibility, research & development, solution development, and merged launch and review. On the average, CompA launches totally new products every four years. Minor model changes are made once a year. NPD project takes usually two to three years. CompA sells products all over the world. They have several production sites across the world. The production volume per model is something like 100-150 machines per year. Customers can vary the basic model by adding some optional features.

CompB's NPD process generally consists of three gates, but the development model is now under development as the company is growing and all the processes are in slight transition. The product development cycle is quite slow; they launch totally new product platforms once in a decade. However, the pace is accelerating in the future.

> *"Our target is to launch new products in regularly basis and more frequently in the future."(#B1)*

A new product development project takes usually one to two years. CompB operates in biomedical technology industry, where the manufacturing cost forms only a small part of the final sales price. Important cost drivers include distribution channels and the product development. The company has invested in own manufacturing capacity so the share of purchased components is smaller than the in other two case companies. The suppliers are mainly from Europe but also from USA and Asia. 98 per cent of the products are sold at global markets.

CompC uses stage gate process in which there are four stages. The stages are called business case, preliminary design review, critical design review, and production readiness. However, the process is varied according to the scale of the development project. In a year there are five to ten new product development projects of which duration varies from couple of weeks to more than a year. Most of the projects are not very innovative and they do not lead to fundamentally new products.

> *"Typical new product development project is about making a bigger or smaller machine and there is not very much anything new or extraordinary. Typically they are copies from each other." (#C1)*

The industry in which CompC is operating is quite conservative and some of the customers even prefer old and well-tried technologies. All the end products are designed according to customer preferences; they have several basic models that are configured to customers. Maintenance service forms important part of CompC's revenue. The CompC has outsourced the majority of their production and they have only assembly plant. Furthermore, they have eliminated majority of the warehouses so the delivery reliability is very critical. They buy high technology components from Finland but the biggest volumes come from China. The characteristics of the case companies are summarized in table 4.1.

Table 4.1. *Characteristics of the case companies.*

	CompA	CompB	CompC
Formal NPD process	yes	under development	yes
Development cycle	4 yrs.	5-10 yrs.	2 yrs.
Duration of NPD project	2-3 yrs.	1,5-2 yrs.	< 2 yrs.
Core capabilities	quality, maintenance services	quality, functionality	flexibility, maintenance services
Decoupling point	assembly to order	make to stock	engineering to order

4.1.2. Concept development decisions

Most concept development decisions are made at early stages of product development process in every case company. At CompA the target specifications for the product are set at the second stage called feasibility stage. The main target set for the new product development project is the target cost of the final product. The target cost is also one of the most important measures when evaluating the development project success afterwards. The target cost is decided by product management.

In company's product development process model the target for supply chain lead time is mentioned but the responsible for target setting is production. Other targets for supply chain are not set in the beginning of the NPD process. However, there are some decisions made at the early stages that have great impact on product design:

> *“Large steel structures are significant cost items and ones that can be influenced by sourcing and product design decisions… Their manufacturing location should be known as soon as possible for it will have an effect on in which form we can deliver it to our production site… If it’s made in China it should be made of bolted parts that are easy to transport in freight containers.” (#A2)*

> *“There are differences in tubular spars between different countries. It is hard to get tubular spars with metric measures from India; they are all made with inch scale.” (#A2)*

Any changes during the later stages to these decisions have naturally a great effect on the duration of the development project or alternatively to the effectiveness of the new product’s supply chain. However, at the moment there is no clear idea about when the decisions are made. The designer states as follows:

> *“It should absolutely be made at the feasibility stage. Does it happen and how well it holds true, I don’t know… However, I know that there have been some changes in the manufacturing locations of the most critical components when the project has proceeded.” (#A2)*

Furthermore, usually the sourcing is not involved in the early stages of the project:

> *”It is not wise to immediately harness a large group of people to do this, if we don’t know in which direction we want to go. It is better that there is only one person who concerns him/herself and lays out the big picture… When it seems this is possible and the big picture is set, then it is possible to share the task with others and we can really start the project and allocate the resources.”(A2)*

> *“When the project has started in full speed the sourcing is tightly involved to the project.” (#A2)*

Modularity is seen as important in CompA and they try to exploit it but only to certain level; their production volumes are so low that further utilization is noticed not to be cost effective. The main components, for example the engine, are decided at idea management or feasibility stage. Similarly, the number of variations is decided during the early stages. Even though there are customer requests for new variations, it is tried to keep in mind that the de-coupling point would be as late as possible.

> *“We try to follow these common principles. And yes, we follow.” (#A3)*

Maintenance and spare part services are important business areas for CompA. However, the product lifetime is not well specified. The product designer states:

> *“The machine is probably recyclable, but I don’t know how much we know what happens after the machine is ten years old.” (#A2)*

Spare part service is involved in the product development process and they take care that the spare part service doesn't unnecessarily get harder because of the new product.

Similarly, at CompB the target specifications are set early at the process. They have been tentatively set before the project starts in full scale. People from marketing, product development and product management are involved in determining the target specifications. However, the participation of different functions is not formalized and the sourcing is not involved at all. During the early stages any materials or components or even product modularity is not nailed down. Those decisions are placed under product developments' responsibility.

> *"In principle it [the product design] is quite free, we trust on each other so we don't need exact specifications. Only the customer preferences are fixed." (#B1)*

However, there are also aspects that would be important to decide during early stages but currently are not. For example, the decision about whether the product will be manufactured in automated line or not should be made before the detailed design work starts. At the moment, these decisions are not always made on time as there are changes in production arrangements during the development process.

> *"Do we assemble the product in automated production line or manually; that is a decision that should be made when the project starts… But there are so many changes in the production that you don't keep up the pace." (#B1)*

The lack of decisions about modularity during early stages complicates the inventory and the logistics. Partly as a consequence, the sourcing manager at CompB has tried to push the idea of increasing commonality in order to improve cost effectiveness and inventory turnover:

> *"I have suggested that product development would have a list of standard components that are already in use in the company… It is costly to maintain many items… It is even more important because we buy small lots. We have components whose minimum lot size is 2000 pieces and it may take 10 years to get that amount used in certain products." (#B2)*

The idea has not gain momentum; at the moment sourcing and product development only discuss the issue but in many cases too late. At that time the design is so ready that it is hard to make changes anymore. Furthermore, the power of decision is in product development's hand and they make the final decisions about the components.

> *"Sometimes we have hot discussions. However, at that time the design is so ready that it is hard to change. The designers have the mentality that what have been done is done." (#B2)*

In general, the late involvement of sourcing in product development process restricts the work of sourcing function. The sourcing is not highly involved in the process before the product starts to get the final form at CompB:

> *"We are involved in not until the product must be made to work industrially. Then we start to search for suppliers whose quality and price match our desired quality and target cost." (#B2)*

The target cost is set before the project starts in full scale but it may be quite rough. For example, the target may be that the new product should be cheaper to manufacture than the previous one. The number of variants is set at early stage but it may slightly change as the project proceeds. This is because the development projects usually take about two years. However, the supply chain issues are tried to keep in mind all the time as the number of variants increases. The commonality is seen important also by product development when increasing the variation:

> *"Of course we consider the production and manufacturing… we have same parts even among different product families… you have to think the whole palette so that the production logistics would go as easy as possible." (#B1)*

CompB has disposable products, so the recycling is taken very well into account during the design stage. On the other hand, the company has also products that must withstand high temperatures and different kinds of chemicals. In that case, there are not many options when selecting materials but the part count has been tried to keep minimal. Those products are also very durable and their lifetime can be more than ten years. As such, the company also offers maintenance services, which account for roughly one third of their total revenue. The maintenance of the products has designed to be as easy as possible:

> *"It comes naturally, there are few parts in our products and they are easy to assemble and disassemble. These are the basic things you think when you design new products. Of course you can disassemble the product of competitors too, but our products are just simpler." (#B1)*

However, the designers don't systematically analyze the result of their design and there are no explicit guidelines for the design work from the view of serviceability. As noticed, the decision on the aftermarket services comes from the company's strategy, but the feasibility and efficiency of the services is defined during the product design in the product development process.

CompC sets a target cost for the product during the early stages of the product development process. Furthermore, they set targets for the lead time. The company designs the products according to customer orders and they do not have any stocks. Problems arise when the delivery time for some components is longer than the aimed total lead time. This in turn affects CompC's revenue, as products cannot be delivered to customers fast enough.

CompC selects their components based on costs, availability and functionality. The use of same components as in other products is not seen very important. However, in the same breath they acknowledge that it may affect the maintenance and spare part services, which is one of their most important business areas.

> *"Of course there is the maintenance aspect. The maintenance maintains spare part stocks and they don't like if we always change the component types. But sometimes we change them and sometimes not. It depends on the availability." (#C1)*

CompC have many variants but they have tried to develop a system in which customers could choose the product features from a ready-made list. As a consequence the variation could be made easier. Furthermore, CompC has invested in production technologies that help the variation.

4.1.3. Supply chain design decisions

Make or buy decisions are partly made at the high organizational levels in every case company. However, part of the make or buy decisions are still made during the product development process. At CompA they must make a decision on how large and ready the modules are when they arrive to the production site. Transportation has the largest effect on the decision and thus the company evaluates the transportation cost against the value added when they make the decision. The product design has been noticed to have a great impact on the goodness of the decision; the modules are easier and cheaper to transport if they are designed so that they fit in a minimum space. One can talk about "IKEA-concept".

At CompB the make or buy decision is largely determined by their manufacturing capabilities. They have heavily invested in certain manufacturing technology so they try to exploit it when developing new products. This has a great impact on the product design, but it is naturally known before the project starts. Otherwise the make or buy decisions are made by product development alone or together with sourcing. The stage at which the decisions are made depends heavily on the importance of the component. Main components have to be decided before others, for they impact significantly on the total design.

At CompC there are explicit guidelines for the make or buy decisions. There is corporate wide process that defines make or buy strategy. In the strategy it has been determined whether components are made or bought or both. The factors that affect the decision are for instance criticality and availability. According to the strategy the production site has its own "strong" work phases that are tried to exploit as well as possible. Especially, the product design is made so that it supports CompC's own "make" capabilities. Furthermore, during the new product development process the designers discuss with the production whether some component should be made oneself or bought outside.

The decision whether the firm chooses to design new component, or to select component from suppliers' catalogs, or from those already in use in the company, is made during the product design in CompA, but their upper level object is that the company uses components that are generally available, not components that have special design.

> *"More and more we try to use commercial components… so that we can exploit economies of scale and cost advantages." (#A3)*

If the designer has designed a new component that is very similar to commercially available component, then the financial aspects will determine the final decision at CompA. However, also the availability must be good, for if there is only one supplier it would increase the risk of the company. The decisions about design or select are discussed by the product designer and the purchasing representative among the other work related to the project. However, one identified problem is that the purchasing personnel do not have enough knowledge about possible component alternatives. The purchasing manager states:

> *"One thing that should be improved is that our purchasing personnel should have more information about current market situation and available options. Then we could assist our product designers and tell about new opportunities for them." (#A3)*

At CompB the design or select decisions is in product development's hands and there are few discussions on the issue as the sourcing is not highly involved in the process in design stages. At CompC there are only a few standard components and most of the components are self-designed. However, the possibilities to use standard components are tried to exploit; the designer states:

> *"Of course, if we can accomplish the desired functionality with standard components, we always use them. We have already enough parts that must be designed specifically." (#C1)*

At CompC the final decision about components is made by product development. However, if the alternative component is more expensive than the standard one there must be good reasons to change. Usually there are no conflicts and the decisions are made with good mutual understanding.

In general, CompA has no preliminary plan for the purchasing as the project starts. The final purchasing plan is made just before the ramp-up and it includes information about the suppliers and their back-up suppliers. When asked, the purchasing manager had some general guidelines for supplier selection:

> *"Flexibility, there must always be an alternative… In the back of our mind is that we should decrease our supplier network… we should focus on the suppliers who can offer large volumes." (#A3)*

The selection of suppliers differs across components. The stage at which the selection is made differs based on the importance of the components:

> *"Suppliers of the largest and most important components are tried to identify at feasibility stage… At the latest they are selected at the research & development stage, but the earlier the better… But if we talk about cheaper components or components that several suppliers supply, then the decisions are made at solution development stage… furthermore, the supplier changes are common." (#A2)*

Furthermore, CompA uses certain prototype suppliers during the product development; they are selected based on previous collaboration and experiences. The selection is made by operational sourcing, who is involved in the development process.

> *"Operational sourcing is involved in our project team and they use partner suppliers who are located near to us, suppliers that are proved to be good ones. We use them when making the prototypes and to get components to the production plant on time." (#A2)*

The selection of the final suppliers is separated from the selection of prototype suppliers.

> *"Later, after we have found the problems in manufacturing, we can use suppliers who don't give that much feedback". (#A2)*

> *"Strategic sourcing is searching for new suppliers all over the world all the time and they give the alternatives for us [product designers]."(#A2)*

On the other hand, in CompA, the selection of new, non-critical components is made by product designer. At that time, also the supplier is known, so the product designer makes the decision regarding to the supplier selection of non-critical components. The selection is made at the solution development stage and the supplier will not be changed unless something crucial happens. The designer states:

> *"I don't think our purchasing wants to take a stand on the supplier selection [of non-critical components]… It is a hard work for them and they might not have required technical knowledge to say if the other component is suitable or not." (#A2)*

Accordingly, it is a product designer's responsibility to ensure that also the component price and availability are reasonable. There have been some problems with availability when selecting standard components in recent years:

> *"The problem is that even though we think the component is well available, the suitability of the component may be hard to specify if it is under different brand. There have been several cases like this when we have moved manufacturing from Finland to USA." (#A2)*

In CompB the supplier selection is not that multidimensional task. Their volumes are relatively small and their technological requirements very special, and therefore the number of possible suppliers is quite small. As such,

> *"The suppliers are naturally eliminated during the selection process." (#B1)*

Thus, they try to centralize their supplies on few suppliers to get more buying power. The company has usually very long relationships with the suppliers and they do not change the suppliers afterwards if there is no specific reason. The most suppliers are old ones even though they also try to find new ones to get new technologies. The most important factors when selecting new suppliers are availability, price and quality. Furthermore, the size of the supplier effects the selection; the company tries to select suppliers that are not too powerful. Furthermore, they consider the delivery reliability and validity, as they try to decrease their stock values.

During the new product development process supplier changes are normal. The company may change the supplier entirely or they may return to the original supplier, sometimes they have several parallel suppliers of which they choose the best at the end of the process. According to CompB's guidelines all new suppliers are first audited. They also ask their supplier candidates an example batch, according to which the quality can be verified. In general, product designers have a great influence on supplier selection. They largely determine the suppliers as they search for new technologies and potential suppliers for them:

> *"I was just at an exhibition searching for new ideas and technologies. I was exploring what is available."(#B1)*

This is especially true as there are no upper level guidelines for supplier selection. Sometimes product development's high involvement in supplier selection makes things more complicated from the view of sourcing. The sourcing manager states:

> *"Sometimes it makes things harder. When product development has discussed with the supplier and possibly made some test series… then the normal trading is a bit complicated as the supplier is quite sure they get the order." (#B2)*

Product designers have a great influence on supplier selection also as the product design sets limitations to the supplier selection. For example, the product development may design a new component, which is so special that there is only one possible supplier. On the other hand, the product development may design slight changes to standard component so that it better fits the product. However, if changes would not have been made, there would be more possible suppliers and it would be easier to change the supplier later.

> *"If we choose one supplier who makes the desired change and the mold, we are almost married to them. This is because supplier change would be so expensive that the cost is not at any rate the reason to do that." (#B2)*

Successful supplier selection during the product development is especially critical for CompB because having a second supplier is not always possible; they have components whose demand is some thousands a year, and it is not feasible to share that amount among several suppliers. When the supplier selection is made the target is to secure that there is other suppliers available if needed.

At CompC prototype suppliers are selected based on the part availability and usually the suppliers are co-located. The selection of final suppliers is quite different to that. CompC has specific sourcing strategy that defines the accepted suppliers for every product category. In order to become an accepted supplier one must qualify from quality and capacity auditing. If there are needs for new suppliers the decision is under purchasing manager's responsibility. The main factors to evaluate the suppliers are costs, quality and lead time. This hasn't been always the truth.

> *"Half a year backwards it was price, price, price, and nothing else… it was made decisions that the quality and the lead time couldn't be right… But we don't have any warehouses; we don't have any purchase inspections… If the purchased product does not meet our quality requirement, it stops the whole production. At the moment we can't afford that as there is not extra capacity." (#C2)*

Switching a supplier is not an easy task. The first supplied pieces are inspected and measured thoroughly. One problem related to the inspection is the dimensional accuracy; the purchasing would need more information from product designers on what the critical tolerances and functionalities are. When changing a supplier the purchasing discusses also with the production and asks previous experiences.

In general, there are always two alternative suppliers for every critical component. However, the customer may want a certain brand to be used for certain component and thus the company must stick to that. Furthermore, due to spare part service they try to use only one supplier for example in bearings, even though there are multiple suppliers available.

CompC differs from the other companies because their product development deliberately tries to avoid making the link between the supplier and the component when designing the product.

> *"It is in one sense a bad thing to link the component to certain supplier. We try to avoid that and if possible we try to design components that can be bought from different suppliers. However, often in the case of more expensive components the design depends on the supplier. For example, a big turning bearing differs across the suppliers; you can't get identical to what we use now from other suppliers." (#C1)*

To illustrate the differences and similarities in decision making concerning supply chain design decisions the participated functions are presented in table 4.2. One line indicates that the function is partly responsible for the decision, whereas three lines indicate the function is highly responsible for the decision.

Table 4.2. *Functions responsible for supply chain design decisions at case companies.*

	CompA					CompB					CompC				
	Marketing	Development	Sourcing	Production	Upper level	Marketing	Development	Sourcing	Production	Upper level	Marketing	Development	Sourcing	Production	Upper level
Make or buy		I	I		II		II	I		II		I		I	III
Design or select		II	I				II					II	I		
Supplier selection		II	III				III	I				I	II		III

There are no big differences among the companies in making the make or buy decision, even though at CompC there is more guidance from upper organizational levels. Also the design or select decisions are made quite similarly among the case companies. However, at CompB there were some problems with the issue. Furthermore, CompB is the only company where sourcing was not involved in the decision making at all. The biggest differences are related to supplier selection. Quite interestingly, CompC is the only company where clear objective for supplier selection is given from upper organizational levels. Furthemore, at CompC product designers deliberately try not to take a stand on the supplier selection.

4.1.4. Product design decisions

One of the core ideas at CompA is to design all parts so that they are easy to make in common machines. They try to avoid special machining methods and special geometries. Few problems have emerged mainly due to old designs made decades ago. The quality of the design is greatly dependent on designer's professional skills:

> *"As long as the product designer knows what is cost effective then the construction is usually easily made with common machines." (#A2)*

The evaluation of the quality of the design bases for the most part on asking offers from suppliers. If the offers are too high CompA may have to redesign the part. Also prototype manufacturers may give ideas on how the cost effectiveness of the design can be improved. Furthermore, product development engineer from productization takes a stand on that the product is suitable for production and gives suggestions about manufacturability and ease of assembly for designers during the product design.

Product designer is responsible for component selection and thus the component commonality in CompA. Primarily they try to use old components, but there is no systematic assessment of the issue.

> *"Every designer is allowed to decide do we need a new component or not. There is no supervision from upper levels. But of course, you have to have some kind of reasons." (#A2)*

One guiding idea at CompA is to design the product so that the wearing parts are similar to ones already in use in other machines. However, if the whole model is changed then the wearing parts are also changed, which naturally complicates the spare part service. However, at CompA a few people from spare part service are involved in the NPD process and their job is to make sure that there won't be major challenges related to new product's launch from the perspective of service operations.

At CompB product design is exclusively made by product designers. They design the product according to principles proved to be good. CompB has many product variants so the commonality between product families has seen to be important. Furthermore, the de-coupling point is kept in mind:

> "*You try to design products so that the final configuration can be made as late as possible. In that case you can use the same sub assembly, which may be manufactured in China, in several models." (#B1)*

However, there are no explicit guidelines for the design process either at CompB and thus, much of the effectiveness of the supply chain is based on the professional skills of the designers. CompB selects materials based on their suitability to the final products. As they operate in medical technology industry, there are high requirements for the materials. Thus the range of suitable materials and further the range of material suppliers are quite narrow. The designer states:

> *"We select the material and the supplier will be determined according to that. The material comes through certain channels. You can't affect that. " (#B1)*

According to the process model, material selections must be made before the last gate, after which first models can be manufactured. In worst case, there have been several material changes during the project, which in turn puts a high strain for people involved in the project. The material changes have resulted from both materials being nondurable and user experience being bad.

As in other case companies, also at CompC there is a clear target to make all the products to be manufactured industrially. However, no formal guidelines for design are set. The component commonality is not seen very important:

> *"We try to use components that are cost-effectively available. We don't see the benefit of using the same components as in existing products." (#C1)*

However, the production would like to increase the commonality of product characteristics across the product families. For example, the welding could be designed to follow the same principles from product to product. In that case, the brackets could be better designed and the automation could also be improved. The production discusses these things with product development, but often too late. The design is already finished and only the major problems are tried to be identified at that time.

As mentioned earlier, one problem related to product design at CompC is the accuracy of design parameters. The production manager states that at CompC the part tolerances are determined based on the component supplier's specifications. However, in other companies they test the tolerances themselves.

At CompC material selection may affect the range of possible suppliers, for example certain steel grade is available only from one supplier; if the company wants to change the supplier it must also change the steel grade. Furthermore, the prices of some metals can fluctuate radically which in turn affects the price of alloy steel. In such situations the purchasing usually asks the product development whether these materials could be changed or not.

4.1.5. Ramp-up and launch decisions

In every case company the forecasted demand is taken into consideration during the early stages as the demand has a great effect on the profitability of the development project. However, changes in demand are not seen that important aspect and they are not further investigated in the beginning of the NPD project. This is partly due to challenges in forecasting:

> *"Life cycle thinking is a bit complicated as forecasting customer behavior is hard… in general, first the demand is low, then becomes a peak, after which the demand will stabilize." (#B2)*

Only at CompA the demand was said to have an effect on product design and supplier selection. Otherwise, the main drivers to evaluate the demand are financial. For example, the person from CompC's product development states:

> *"Long term demand and profit estimates are evaluated during the business case evaluation. The decision [about starting the project] is made based on net-present value analysis." (#C1)*

Furthermore, CompA's product designer states:

> *"The larger the forecasted demand the more important it is to work on the product design and manufacturing." (#A2)*

4.2. Use of practices that enhance alignment

In chapter 2.4, several practices were identified that may improve the alignment between NPD and SCM. In this section it is investigated how case companies have adopted there practices.

4.2.1. DFX and concurrent engineering

CompA does not use systematically any DFX methodologies. They trust on the skills of the designers.

> *"It depends highly on the chief designer and the individual designers." (#A2)*

The situation is same at CompB. They do not have any formal methods for DFX or concurrent engineering but they discuss on these things and everyone follows the principles as he or she sees the best. The product designer states:

> *"The manufacturability and the costs are the most critical factors. You think all the time how easy and cheap it is to assembly when designing it. There should be minimal amount of parts and so on." (#B1)*

Especially their own manufacturing technology poses straight requirements for the product design. It is noteworthy, that according to the product designer the alignment of these two aspects is one of the core capabilities of the firm. Also at CompC DFX thinking is in use, but neither there is it formalized.

> *"It comes naturally, when we make a design we make it for production and purchasing." (#C1)*

There is production readiness gate in their process model, in which the manufacturability issues are finally went through. However, the decisions are made far earlier. As such, the skills and activity of the project manager affect the issue.

4.2.2. Target-costing and value engineering

Target costing is in constant use at CompA. In the beginning of the project the target cost is set for larger sub modules and parts but as the project moves on the target cost is broken down into individual part level.

> *"The target cost is broken down to as sensible level as possible. In many cases it is at individual part level… I think that as long as people talk about project level costs, it is for the most part rhetoric. There is no flesh on the bones as long as it is not concretized what does it really means." (#A2)*

The costs are seen as the most crucial factor in product development. The designers and the sourcing have conversations on how much the part should cost and what is the cost structure.

Also value engineering is mentioned in CompA's product development process model, but in reality it is used only if there are two distinct options. The use is not systematic.

> *"It [value engineering] is mentioned in our process model as a systematic tool, but in real life, it is used more on the side. For example, it is not like we have done the value engineering and then documented it." (#A2)*

CompB uses target costing only as a rough tool; the target can be as approximate as making cheaper product than the existing one. On the contrary, CompC uses target costing constantly. The target cost is set first for the whole assembly. The product development uses that as their target and they do not set any more detailed target costs. On the other hand, purchasing count very detailed target cost; under purchasing there is a separate team that count so called "should cost" for every component. Based on the "should cost", the purchasing negotiates with the suppliers.

4.2.3. Supplier integration

CompA has selected a couple of suppliers, who participate in development process as prototype suppliers. Their job is to supply modules or subsystems for prototypes and give feedback on manufacturability and design. CompA has noticed several benefits of having these kinds of prototype suppliers: the suppliers are located near the CompA and thus the face-to-face communication is possible at short notice. Furthermore, the prototype suppliers know the preferences of the company so the documentation and drawings does not have to be that detailed. Suppliers may also suggest improvements that lead to cost reductions.

> *"I think it is very good that we have prototype suppliers who are committed to high quality and high delivery reliability, with higher price of course." (#A2)*

> *"When you call them and say, let's not do like in drawings, let's do like it would be best, they do so and they are very flexible." (#A2)*

Supplier integration has become more important as the rate of sourcing has increased:

> *"We haven't done sheet metal work at this site for ten years… Now as the work has transferred to subcontractors it is important that they are closely located and good friends with us. Thus we can collect information very effectively and exploit it in our product design." (#A2)*

Especially new 3D technology would enhance the utilization of suppliers' knowledge. One of the interviewees said:

> *"Sometimes we only have 3D pictures but already that time we can ask our suppliers what do they think, what the price would be, what is the most expensive thing, and after that we can change the design and the technical drawings according to which the final order would be made… this is the idea we should focus on." (#A1)*

However, CompA wants to own all the intellectual property rights of the designs because of the brand, product liability and product ownership issues.

> *"If we own the intellectual property rights, we can change the suppliers quite easily. But if someone else owns them, we are stuck to that supplier." (#A3)*

Despite the importance of the supplier integration at CompA, neither the stage in which the supplier integration happens, nor how the integration should happen have not been clearly defined. There is no notation about suppliers' role in CompA's product development process model either.

At CompB suppliers do not contribute to product development as much as at CompA. At CompB they have discussions with the component suppliers, but the problem is that the suppliers' know-how is not sufficient to CompB's needs.

> *"I hope the suppliers would be more involved [in our product development] but it is very rare that you meet a true expert. The Finnish suppliers are usually one-man companies that sell many products; it is not very fruitful situation from the perspective of new product development." (#B1)*

CompB design all their outsourced components by themselves, since the final products are very integrated. They use supplier knowledge mainly in order to improve the manufacturability of the outsourced parts. At the moment they are testing a system, in which the design documents are shared with the supplier and the supplier can comment the drawings beforehand. However, printed circuit boards are an exception to the previous rule; they are ordered mainly from one supplier, who is closely involved in the design. This is because CompB does not have the required knowhow to do circuit board design themselves.

CompC is trying to exploit the supplier knowledge better than before; they have just launched a new position which should enhance the supplier integration. The job of the new person, who acts as a production engineer for purchasing, is to be in close connection with the suppliers. The target is to develop suppliers' processes and on the other hand benchmark the best practices. In one way, the person acts as a link between the suppliers and the product designers. In general, CompC makes very long delivery contracts and they try to develop the operations together with the partner suppliers.

Attitudes towards supplier driven design at CompC are two-sided. As well as at CompA, at CompC they are afraid of increased supplier power. The purchasing manager states:

> *"We don't want to commit to one supplier. As a rule, all designs should be our own. However, we should exploit our suppliers' knowhow as much as possible." (#C2)*

However, there are components that must be designed together with the suppliers because CompC does not have enough knowhow to design the most demanding parts themselves. In some cases CompC first sent a proposition for the supplier after which the supplier gives their proposal for improvements. There are also parts of which design CompC has no experience. In that case the supplier designs them according to CompC's needs.

> *"We are in close symbiosis with our certain suppliers… There is problem as the purchasing has targets for cost reductions, and of course it would be good from their perspective to have general specs for components so that they could shop around with the suppliers in order to get the best price. Unfortunately, this is not always possible. Especially, in the case of most demanding components the supplier and the design can't be separated." (#C1)*

The stage at which the collaboration occurs differs based on the component criticality. There is no collaboration with suppliers who supply parts that CompC can design itself. They only contact the supplier when the first purchase is to be done. On the other hand, CompC collaborate from the very beginning with suppliers who supply the most challenging parts. However, the number of such suppliers is small; there are only two to three such suppliers. CompC has certain contact persons from these supplier companies.

All the case companies' suppliers contribute very little to new product idea generation. CompA's suppliers' main impact on the new idea generation is at module or component level. For example, the supplier may have developed a new technology for a certain module, which is cheaper or more suitable. The interviewee though that the industry is too conservative for larger exploitation of suppliers' new technologies:

> *"I think the industry is so conservative that there is no new technologies that would change the whole concept… the development of the main components are in our own hands." (#A2)*

The situation is quite similar in CompB even though they apparently search for new innovation more regularly.

> *"We try to constantly search for new ideas from suppliers. However, those situations are quite rare; usually the technologies are already quite old at the time a Finnish supplier can offer them. So the new innovation usually doesn't come as a surprise." (#B1)*

As such, the product designer does not see any radical opportunities coming from suppliers. One reason for this might be the company culture, as the management has wanted neither to use other's innovations nor pay for patents. The culture might be changing for the product designer believes that in the future they might cooperate more for example with universities and participate more in different kind of networks.

Neither the suppliers of CompC participate in new product idea generation:

> *"Our suppliers don't give any contribution to the core of our products. The required know-how is so special." (#C1)*

4.2.4. Knowledge sharing

In general, the knowledge sharing in all case companies happens mainly at regular project meetings. However, the persons who participate in the meetings vary. In CompA internal project team see each other in weekly meetings, in which the project manager and people from design, manufacturing, purchasing, and spare part service are present. The meetings are started when the project starts in full scale. Furthermore, the project team has a shared project folder in which the project documentation is collected. At CompA there is one person, who participates full time in the product development process but is working for purchasing department. The person acts as an integrator between product design and purchasing. Furthermore, At CompA they have a vendor manager who communicates with suppliers supplying standard components.

CompB has also weekly project meetings. The number of participants depends on the project scale but usually there are representatives from all functions. Besides the weekly meetings, the knowledge is greatly shared informally. CompB benefits from the fact that their personnel are co-located and thus information travels faster and one can ask help from others immediately if problems or questions appear.

CompC has project meetings every week, but only product designers are participated there. The purchasing and production are participated in the meetings once or twice in a month. The problem is noticed at the company:

> *"We should improve the way how production and purchasing are linked into our product development projects. It is clear that they should be there but it is not that simple. The basic problem is that every function has its own performance measures and in a matrix organization every function keeps watch on their own measures, which may not be aligned. Sometimes we have to collaborate off the record; these are the problems of a heavy organization structure." (#C1)*

Communication occurs in emails, phone calls and face to face meetings. In some projects they have also used intranet based review system; during the prototype manufacturing production personnel could write down found problems so that designers could see them immediately. Furthermore, CompC has also organized a special event, where the internal functions and the suppliers went through the new product from part to part. From the company there were people from product design, purchasing, production, and quality management and all thought how the parts could be improved.

The knowledge sharing between the focal company and the suppliers is neither systematic nor regular in any company. The person from CompA states:

> *"I see there is no systematic approach to that [communication between product design and prototype supplier]… the chief designer handles the task as he or she sees appropriate. It works by email, by phone, rather lightly, as flexible as possible… If necessary, we visit the supplier." (#A2)*

Actually the communication between supplier and product designer is tried to keep at minimum level at CompA. The communication primarily happens through buyer, who acts as a link between designer and supplier. Reason to this is commercial, for the job of the buyer is to find the most cost-effective and flexible solution. On the other hand, supplier and the designer have the technical knowledge. As a consequence, if there are any technical challenges, supplier and designer must communicate with each other.

At CompB they have noticed that the use of supplier knowledge should be improved. Their product designer wishes for a system in which supplier knowledge would be collected together:

> *"All the meetings, information, components, and our own analysis. How could that all be centralized in one place so that the information would be easy to get?" (#B2)*

At the moment they have to ask each other if someone would know something about the suppliers. It is still quite easy as the company is small and most of the people are co-located, but the situation is changing as the company grows. A good example of informal communication is sourcing manager's daily chatting with designers.

> *"I am used to visit the product development almost every day and having discussions with different people responsible for different things… it takes the issues so much forward very fast. On the contrary in the meetings, if you haven't put everything down, all of the issues will not be brought out." (#B2)*

CompC has a couple of suppliers with whom they communicate very frequently. They are suppliers who are somehow involved in the product design. On the contrary, the knowledge sharing with suppliers of standard components is low. As mentioned earlier, at CompC there is one person who acts as a link between suppliers and product development.

4.2.5. Summary of aligning practices

The use of alignment practices is summarized in following table 4.3.

Table 4.3. *Summary of aligning practices.*

	CompA	CompB	CompC
DFX and concurrent engineering	not systematic, dependent on designer's skills	not systematic, dependent on designer's skills	not systematic, dependent on designer's skills
Target costing and value engineering	in constant use, broken down into individual part level, many discussions between purchasing and product development, value engineering used if needed	approximate tool, not in constant use, value engineering not in use	in constant use, broken down into individual part level by purchasing, product development uses only upper level targets, value engineering not in use
Supplier integration	some "grey box" suppliers as prototype suppliers, design buyer driven, no formal guidelines for integration	some "white box" suppliers, design totally buyer driven, no formal guidelines for integration	some "grey box" suppliers, design partly supplier driven, no formal guidelines for integration
Knowledge sharing; internal	weekly project meetings in which people from internal functions are involved, one person who acts as an integrator between product design and purchasing	weekly project meetings in which people from internal functions are involved, informal face to face communication in great importance	weekly meetings but purchasing and production are involved only once in a month, some experiments of intranet based communication systems and joint design happenings
between focal firm and suppliers	vendor manager	no systematic approach	one person who acts as a link between suppliers and product development, one experiment of joint design happening

4.3. Identified challenges of global supply chain

CompB has two production sites in Finland and one in China. The final production location affects the designing of the product:

> *"Basically they have same equipment in China, but of course you consider more the ease of assembly and other things so that there won't be any hazards. The Chinese just say yes yes, and you never know what they really get done." (#B1)*

This is true at CompA too. If they change the manufacturing location afterwards usually people from Finland travels to the new location to guide the manufacturing process. Furthermore, CompA has had problems in securing whether some components are globally available or not; some components are easy to get from certain country, but their construction may slightly differ from country to country, making it impossible to source elsewhere.

At CompA they have specific targets for purchases from low cost countries. Also CompC has set target for low cost country sourcing. However, there are some problems related to the targets as the definition of low cost country sourcing is not clearly defined.

> *"We just had discussions like it would be nice to buy basic components from low cost countries… However, we are buying all the time! There is just Finnish supplier of imports between. We can't buy single bolts from China." (#C2)*

On the contrary, CompB is purposively decreasing their share of purchases from low cost countries. Especially the China has become less attractive alternative for them:

> *"For example, we are all the time moving our purchases from China back to Europe. This is mainly because of the cost structure, not only because of the quality. The level of costs is already so high in China that there is no idea to buy from there anymore." (#B2)*

The increase in costs is problem for CompB as their order quantities are very small. Furthermore, in China the documentation is not at high enough level, which is particularly important in medical technology industry.

> *"Of course we can get the certifications from there [China] too, but we can't trust on them. As a consequence, we have to do all the work here again. If we count the total costs, even Switzerland is cheaper than China." (#B2)*

As a consequence, CompB's purchasing manager has set a strategic objective to move all supplies from China to elsewhere except the supplies needed by company's own plant in China. However, even then they can't buy straight from Chinese companies, but they have to use global companies that operate in China to secure the quality.

CompC sources major part of their steel structures from China. Their biggest risk there is the revaluation of Chinese currency.

> *"If Chinese currency revaluates 20 per cent it is still profitable to source from there. However, if it revaluates from 40 to 50 per cent, we have a problem. Furthermore, our volumes from there are so large that we can't change the source of supply during one night. Thus, we should have some kind of dual regional purchasing system." (#C2)*

Furthermore, the transportation times from China have increased lately. This is due to high oil prices, whereupon the ships are driving slower and they do not leave the port before the ship is fully loaded. Partly because of this, CompC cannot source project based components from China anymore. Also CompA has noticed increasing costs related to sourcing from low cost countries; long lead times have increased the amount of invested capital.

Most of the identified challenges are related to sourcing form low cost countries. The challenges are summarized in figure 4.1.

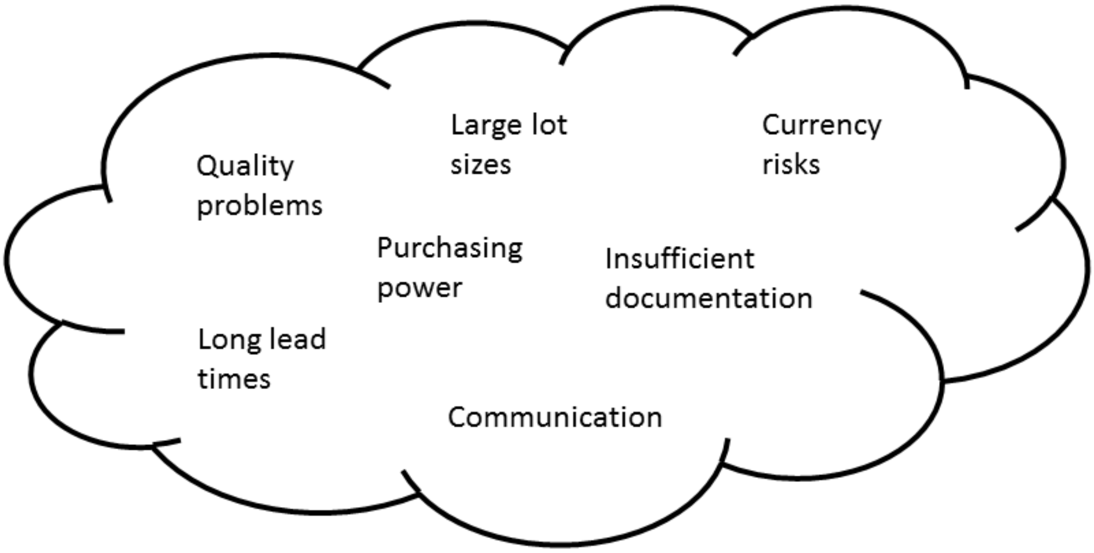

Figure 4.1. *Challenges of operating in low cost countries.*

To great extent the challenges have something to do with the characteristics of the final product, for example the quality, delivery time, documentation or price. As a consequence, if sourced from low cost countries the customer preferences are not always met.

5. DISCUSSION

5.1. NPD decisions affecting supply chain management

Previously identified new product development decisions are illustrated in their wider context based on the results of the case study in figure 5.1. According to the original categorization, the concept development decisions are colored with black, supply chain design decisions with blue and product design decisions with red. The figure is not supposed to be all-inclusive and the links between the decisions are not exclusive to others. The ramp-up and launch decision are not included in the figure.

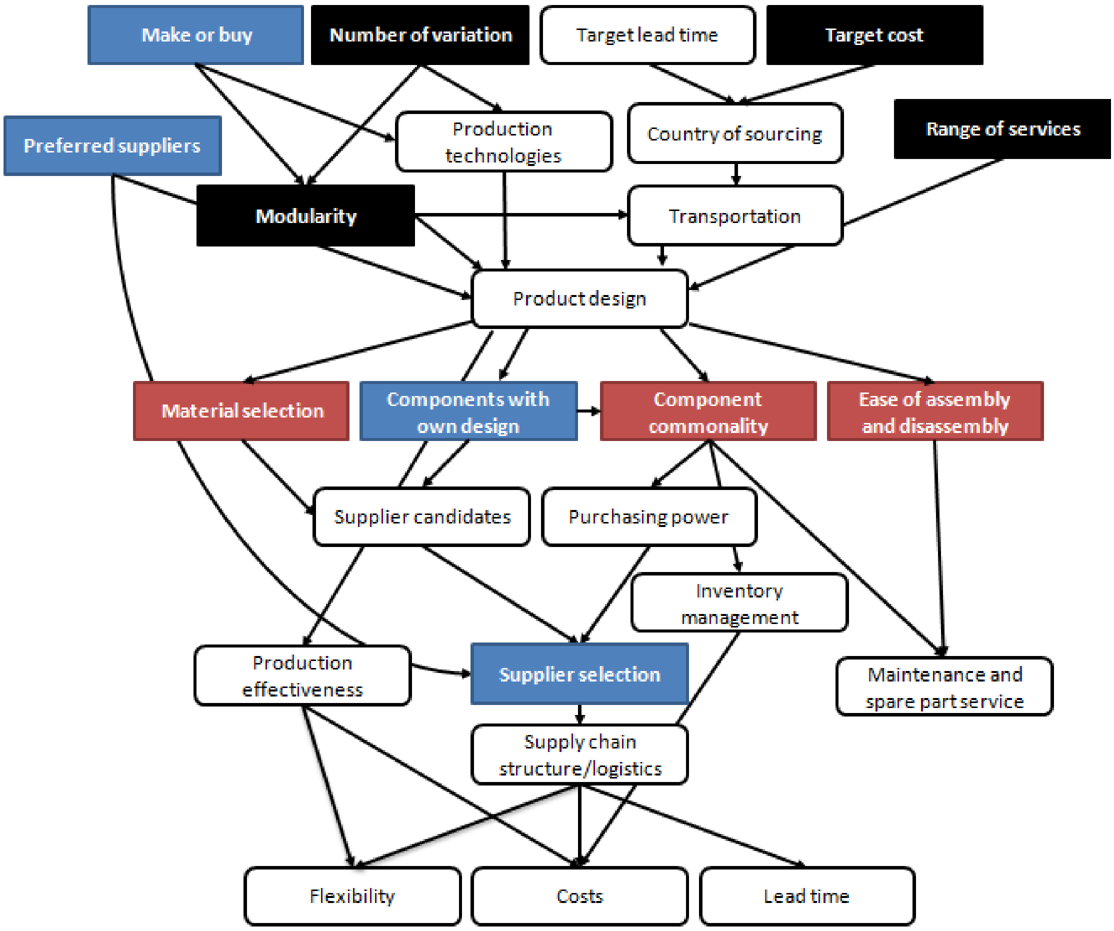

Figure 5.1. *Context of NPD decisions from the view of supply chain management.*

As it is possible to notice, the decisions making environment in new product development project is anything but simple. However, there are issues to subject for further discussion.

5.1.1. Possibilities to influence new product supply chain

Figure 5.1 indicates, that there is one factor that seems to link most of the decision making issues together; the product design. It can be concluded that product design divides the new product development decisions into two parts; decisions made before the product design and decisions made after the product design. The importance of product design as a determining factor is noticed also in other studies (Blackhurst et al. 2005; Khan et al. 2012).

According to that notation, it can be concluded that after the detailed product design has been started, there are less and less possibilities to influence the supply chain of the new product. This is because the product design defines to great extend the playing field in which the remaining supply chain decisions can be made. When the product design is ready, the possibilities to influence the supply chain are quite similar to situation the product is already launched. The idea is illustrated in figure 5.2.

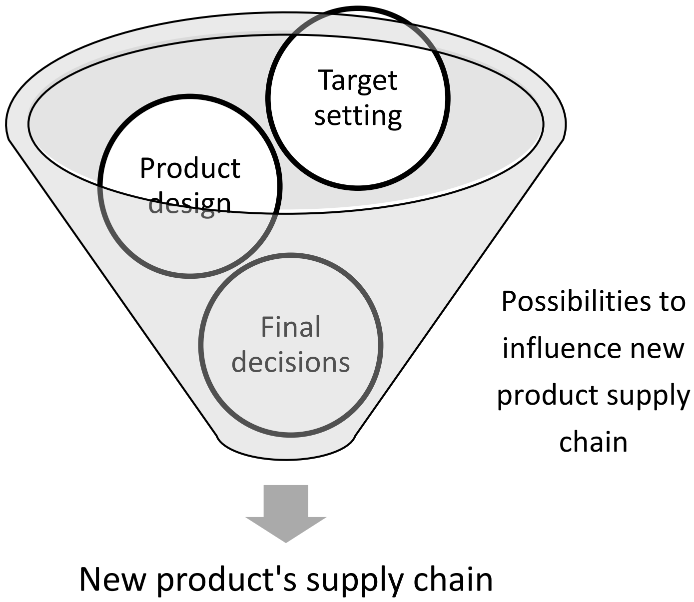

Figure 5.2. *Possibilities to influence the supply chain of new product.*

Accordingly, the best way to improve the alignment between SCM and NPD is to have a clear idea on desired supply chain before the designing of new product starts. To be precise, this means that there should be a target for supply chain at latest in stage called business case considering the Cooper’s (2008) model presented in figure 2.1. This supply chain target should guide the design process so that the new product could be delivered at the targeted cost, time and quality, as stated by Pero et al. (2010).

5.1.2. Supplier selection during NPD project

Another notable finding identified from case results and figure 5.1 is that the supplier selection during new product development project is highly multidimensional decision and should be divided into several sub decisions. Based on the case study results, there were differences in supplier selection depending on the criticality of the supplied item. This finding is consistent with old categorization introduced by Kraljic (1983) and the restructuring of supplier selection methods presented by de Boer et al. (2001). The suppliers, and thus the supplier selection during new product development can be categorized into three supplier classes; *prototype suppliers, suppliers of critical items*, and *suppliers of non-critical items*.

The prototype suppliers are ones that largely participate in the development project, even though they might not be part of the supply chain after the product has been launched. Usually company has a long relationship with these suppliers and they are co-located. On the spectrum of supplier integration (Petersen et al. 2005) the prototype suppliers can be described as "gray box" suppliers. Accordingly, there is a joint development activity between the buyer and the supplier. The selection of these suppliers is usually linked to previous experiences or the location of the supplier. An important point is that the selection of prototype supplier does not have to have any connection to the traditional supplier selection criteria, such as quality, delivery performance and cost (Weber et al. 1991).

A supplier of critical item can be defined as a supplier, who supply item that has high supply risk or extremely high profit impact. The selection of these suppliers is noticed to be made, or at least tried to make, at early stages. This is consistent with research of Handfield et al. (1999). Decision making varies among the case companies as in other companies there are more formal procedures whereas in other companies not. These suppliers are usually by nature "grey box" or "black box" suppliers (see Petersen et al. 2005). "No involvement" is not possible as buying a strategic item is often quite complex task. On the contrary, suppliers of non-critical items sell items, which are easy to buy or have low profit impact. Usually the supplier selection regarding these items is made during later stages when the detailed product design is already in progress. Also this supports the results of Handfield et al. (1999). Supplier involvement is not needed as the relationship between buyer and supplier is transactional.

As Kraljic (1983) note, the decision level when selecting supplier of critical item should be either top or higher level. On the contrary, the supplier selection of non-critical items should be made at medium or low organizational levels. Among the case companies the responsible for supplier selection greatly varies. At CompC the decision regarding supplier selection for new products is made by sourcing and the product designers purposively try to avoid affecting the decision. Quite contrary, at CompB the product designer purposively searches for new suppliers and further has a great influence on supplier selection. Furthermore, the supplier selection during new product development is greatly dependent on previous decisions; most of the suppliers are same as in older products. Also Appelqvist et al. (2004) note this and divide the managerial situation into situations of *breakthrough* and *design for logistics* depending on whether the supply chain remains unchanging or is new when new product are developed.

5.2. Revised framework for decision making during the NPD process

Based on the case study results, the conceptual framework presented in figure 2.13 has been up dated and is illustrated in figure 5.3. The framework highlights the importance of strategic planning and decision making at the early stages of the NPD project. The objective of the framework is to support the decision making during the NPD project in order to achieve better alignment between the new product and its supply chain.

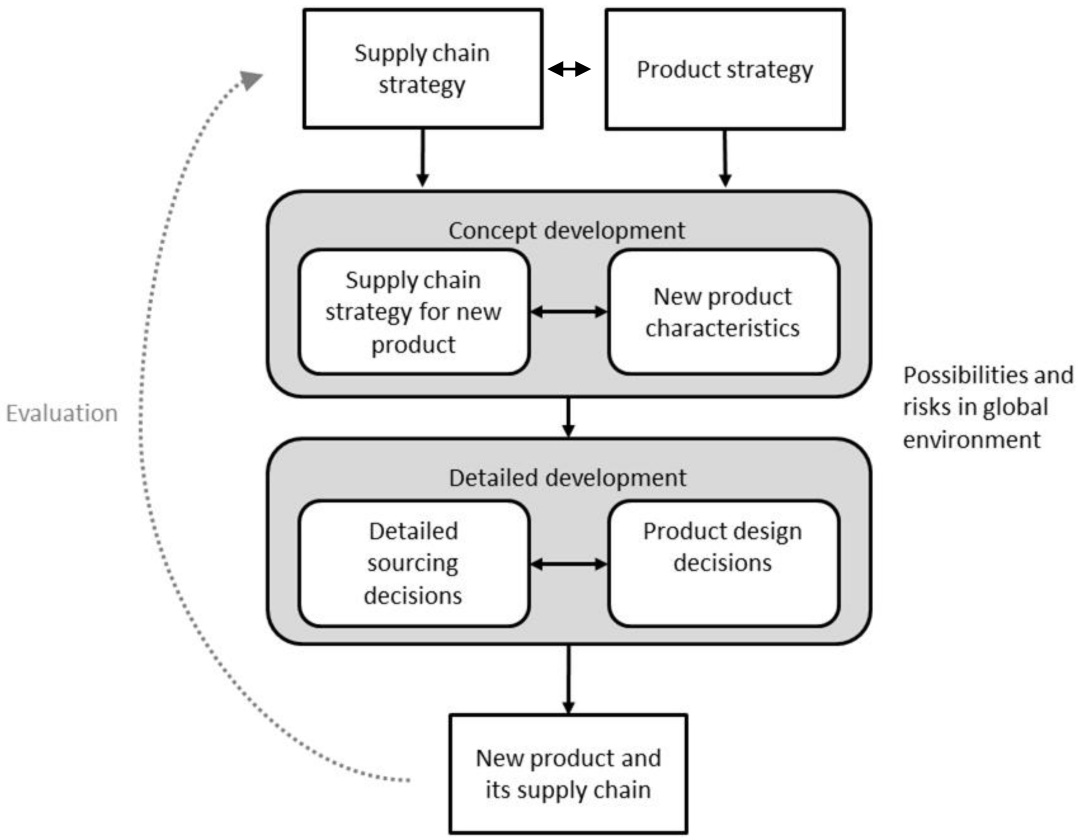

Figure 5.3. *Revised decision making framework for NPD project.*

According to the revised framework, the decision making during NPD project can be fallen under four headings; strategic planning, concept development, detailed development and evaluation. In addition to that, the possibilities and risks in the global environment should be taken account at each decision making stage.

5.2.1. Strategic planning

There is a great deal of strategic planning decisions which should guide the NPD project. These decisions are of strategic importance and they reflect the company strategy. These decisions are apart from the NPD project as they take a stand on the entire product range and total supply chain strategy. The idea is similar to Van Echtelt et al.'s (2008) conclusion, according to which, in order to achieve successful involvement of suppliers in new product development, one must take account not only project-specific issues but also strategic and long-term issues. Accordingly, in order to improve NPD and SCM alignment there should be a shared vision on strategic issues among the people involved in the development project. These upper level strategies should guide the following NPD project so that the remaining decisions would be consistent with the upper level strategies.

The idea of product strategy as a starting point for NPD process is already well covered in the NPD literature (Cooper 1979; Barczak 1995), whereas the importance of connecting supply chain strategy with new product development is not discussed in much detail in the literature. However, based on the case study results following strategic supply chain issues should be connected to new product development process:

- make or buy
- supplier strategy, and
- commonality.

Make or buy decision has been found to be made at high organizational level (Handfield et al. 1999) and to be of strategic importance (Stuart 1997; Handfield et al. 1999), which is consistent with the results of the case study. However, the implementation of the make or buy strategy is dependent on the NPD process and thus the proper understanding of upper level make or buy strategy among the NPD team is vital.

In addition to the make or buy strategy, also upper level supplier strategy should guide the NPD project. It should be defined using long-term objectives and it should take a stand on the relationship with different suppliers and the overall supplier base. For example, Wynstra et al. (2001) state that the problems related to supplier involvement may result from lack of a clearly defined product development process and strategy. Wynstra et al. (2003) further state that in order to successfully involve suppliers into new product development, there must be general policies and guidelines for supplier involvement in product development, and for technological areas in which to collaborate. For example, as discussed in chapter 5.1.2, the selection of prototype suppliers is a strategic decision that should be defined outside the NPD project.

These two decisions; make or buy and the supplier strategy, are well covered in strategic supply chain management literature. However, the last decision about the level of commonality is not. Even though it might not be strategically that important, it may yield significant cost savings as stated by Perera et al. (1999). However, if there is no upper level aim for commonality there is a big chance the cost savings will never be fully exploited. This is especially true as the biggest benefits of commonality materialize in day-to-day operations, not during the product development project (see Labro 2004). As a consequence, the product designer may not take these issues into consideration without the upper level interest in the matter, especially because the commonality may collide with other new product targets, such as differentiation strategy (Kim & Chhajed 2000). Thus, it would be far more important to align these opposite targets with each other, already before the new product development project starts.

5.2.2. Concept development

In order to carry out the upper level strategic goals during the NPD project, it is essential to communicate the desired strategy properly to the development team. After that, the tactical NPD decisions are more likely to be made consistently with the upper level strategies. Based on the literature review and the case study results, besides determining the characteristics of the new product, a target for new product's supply chain should be determined during concept development. Concept development refers to all stages prior to the development stage (see figure 2.1).

At the moment, formal target setting for new product includes a target cost and target specifications concerning product functionalities. In addition, during the concept development companies evaluate the profitability of the NPD project, including the forecast for product demand. However, there are many other issues that should be taken into consideration more systematically in order to ensure the alignment between the final product and its supply chain. The idea is similar to Mason-Jones et al.'s (2000) idea about matching supply chain design to the actual needs of the marketplace. They state: "*Getting the right product, at the right price, at the right time to the consumer is not only the lynchpin to competitive success but also the key to survival. Hence, customer satisfaction and marketplace understanding are crucial elements for consideration when attempting to establish a new supply chain strategy."* However, the idea can be inverted; when developing new products, the key to survival is that the product is available at the right price, at the right time to the right customer. Consequently, the supply chain issues should be taken into account already during concept development in new product development process. In other words, supply chain target should be set at the same time as other product characteristics.

Based on the literature review and the case study results, the issues to take into account at early stages of new product development project are as follows. Product related issues include decisions about:

- target cost
- competitive advantage
- service offering
- variation, and
- demand across life cycle.

Supply chain related issues include decisions about:

- target lead time
- de-coupling point
- production technology
- country of sourcing and manufacturing, and
- suppliers of critical items.

The product related issues define the characteristics of the new product and the supply chain related issues define the desired supply chain for the new product. Naturally, these both targets should be aligned together. For example, if there are many variants from the product, it would be desirable that the de-coupling point would be as late as possible. As discussed in chapter 5.1.2, the supplier selection regarding strategic items should be made at early stages. This is essential, as based on the case study results these decisions may have a huge impact on the detailed product design, or the product development time, if parts cannot be supplied early enough. Similarly, it was found that the country of sourcing and production technology may largely affect the detailed product design and should thus be decided during the early stages.

When making supply chain decisions, the global environment, both possibilities and risks associated to it, should also be taken into consideration. Problems arise when the sourcing decisions are not aligned with the company itself or its products. Especially, the case companies have noticed some side effects in outsourcing to low cost countries. For example, there is no idea to buy cheap but not so good quality components from China if the main competitive advantage of the product is good quality. As a consequence, the decisions regarding the supply chain should not be made based on the costs but based on the total performance. This supports the previous literature described in chapter 2.3.1.

5.2.3. Detailed development

Detailed development refers to development stage in which detailed design is set (see figure 2.1). At that time the biggest decisions should be already made and the product designer can focus on the design work. Product design decisions include detailed decisions related to:

- material selection
- component commonality, and
- DFX.

Detailed sourcing decisions on the other hand include:

- supplier selection for routine and leverage items.

Naturally, these decisions should be made the previous targets and decisions in mind.

5.2.4. Evaluation of realized supply chain

During the launch and ramp-up stages the final supply chain starts to form. At the moment none of the companies evaluated their new product from the view of supply chain management. The boundary between the new product development and the day-to-day operations was evident; possible problems were left for production or purchasing and the people involved in the development project might never hear about them.

However, the new product supply chain should be evaluated based on the performance meters described in chapter 2.3.1. They can be summarized to include flexibility, output to customers and total costs. Furthermore, as illustrated in figure 5.3, these performance meters should be consistent to those upper level strategies and targets, which were set for the product and its supply chain in the beginning of the project. The idea is similar to Beamon's (1999) point of view, as she states that inadequate measures can lead inconsistencies with the strategic goals of an organization. Especially, the output to customers should be consistent with the product's competitive advantage.

5.3. Possibilities of improved alignment in industrial markets

The previous research has demonstrated the benefits of the alignment of NPD and SCM in fast paced consumer markets. One of the most important factors in consumer markets is to avoid lost sales and disappointed customers and thus ensuring the product availability is supply chain management's most important issues as new products are developed (van Hoek & Chapman 2006; Khan et al. 2012). However, in industrial markets where the development cycle is not so fast and new products are launched less frequently, the possibilities of improved NPD and SCM alignment are a bit different.

Based on the exploratory case study several possibilities of improved alignment were identified. Firstly, it was noticed that early sourcing of critical components with long lead time can shorten the development time and thus decrease the time to market. If components with long lead time can be identified and thus sourced at early stages, the prototypes and the first products can be manufactured earlier and thus the time to market can be decreased.

Furthermore, improved knowledge sharing during the early stages and actual development stage may improve the performance of the resulting supply chain and the success of the new product. The need for greater knowledge sharing is evident both between internal functions and between the focal firm and the supplier. For example, one of the missions of sourcing is to get information about the possibilities in supplier markets. If they succeed in this mission and further efficiently feed this information into new product development, it is likely that there will be less last-minute changes in the end of the project. Furthermore, if right suppliers are involved in the project and the knowledge sharing is sufficient, even long-term benefits are possible (Wynstra et al. 2001).

Furthermore, it was found that improved component commonality may simplify the inventory management and may increase company's buying power. Furthermore, if the product design is made the logistics in mind, the logistics costs may diminish. Finally, in case that improved alignment of NPD and SCM leads to situation, in which new product can be delivered the customer at right cost and at right time, the alignment increases the total customer value. The identified possibilities of improved alignment are summarized in table 5.1.

Table. 5.1. *Identified possibilities of improved alignment in industrial markets.*

#	Improvement	Impact
1	Early sourcing of critical components with long lead time can shorten the development time	time to market
2	Improved knowledge sharing during the early stages and actual development stage may decrease the number of last-minute changes	time to market, supply chain performance
3	Aligned design may decrease logistics and inventory costs	supply chain performance
4	Improved alignment may increase customer value	company performance

However, most of the identified possibilities of NPD and SCM alignment lay in the upper right corner in Van Hoek & Chapman's (2006) framework, which was presented in figure 2.5. Thus, the alignment must happen in the very beginning of the development process and the product development and supply chain management must have a joint mission. Accordingly, the revised decisions making framework presented in previous chapter would enhance the chances to exploit the identified possibilities.

6. CONCLUSIONS

6.1. Managerial implications

The rate of new product introductions is increasing. At the same time, the interdependency on suppliers is increasing since the companies no longer own all the knowledge required to develop and manufacture new products. Furthermore, it is not enough to develop successful products; they must be delivered to customers at the right time, at the right cost and at the right quality. Accordingly, the greater alignment between new product development and supply chain management is needed.

At the moment new product development and supply chain management are seen as separate processes and there are no explicit guidelines on how supply chain issues should be taken account during a new product development project. Consequently, a new approach to new product development decision making is needed.

The wider decision making framework for new product development project was introduced in chapter 5.2. Based on that, it can be suggested four concrete proposals for action in order to improve the NPD and SCM alignment:

1) Set clear target for the upcoming supply chain in the beginning of the NPD project
2) Adopt more systematic approach to internal knowledge sharing at early stages
3) Adopt more systematic approach to supplier integration
4) Evaluate the alignment of the new product and its supply chain afterwards

First of all, at the moment a clear idea about new product's desired supply chain is lacking. It would be essential to explicitly communicate the target supply chain through the development team. In that case, the possibilities to achieve a supply chain that supports the core capabilities of the product would increase a lot.

Secondly, there should be more systematic approach to knowledge sharing between different internal functions during the early stages of new product development project. At the moment, the project manager has the biggest burden of knowledge sharing and in every case the knowledge sharing is not sufficient during early stages. The knowledge sharing is important since better involvement of purchasing and sourcing in the early stages of NPD project would facilitate the later stages of the development project. In addition, the knowledge sharing during early stages might be more efficient than during later stages, with reference to the notation that the possibilities to affect the resulting supply chain reduces greatly after the product design has been determined.

Furthermore, a more systematic approach to supplier integration would be beneficial. The benefits of supplier integration are already widely acknowledged in companies, even though the procedures related to it are neither well documented nor systematically analyzed. Therefore, it should be noticed that supplier integration is not always beneficial, but it should be integrated with strategic decisions on make or buy capabilities and supplier partnership. If conducted properly, the results can be seen for example in decreased time to market, better product functionalities and easier assembly and disassembly.

Finally, it would be important to evaluate the new product and its supply chain together after the product has been launched. If not done, important information about future improvement possibilities in new product development process, product design or supply chain design is lost.

6.2. Academic contribution

In the literature there are many calls for better alignment of new product development and supply chain management. The focus has been on the alignment of product development and supply chain management processes (Hult & Swan 2003; Tomas & Hult 2003), on coordinating product design, process design and supply chain design decisions (Rungtusanatham & Forza 2005; Forza et al. 2005) and on the idea of leveraging supply chain in new product development (van Hoek & Chapman 2006; 2007). However, to date there is no previous research on how and when supply chain related decisions are made during the new product development project or even how the alignment between NPD and SCM can be achieved.

This thesis greatly clarifies the decision making process that leads to a new product and its supply chain and thus covers the previous research lack. The knowledge of these decisions and their effects makes it easier to make decisions that lead to better total performance, not only better NPD or SCM performance. Consequently, this thesis combines two research streams, the research on operations and supply chain management and the research on new product development. These both research areas are also important business processes and they have many similar characteristics; their ultimate goal is to add value for the end customers and they both cut interorganizational boundaries. Furthermore, both of them yield significant sources of competitive advantage. Therefore, aligning them may yield opportunities that have not been found yet. However, this thesis guides the research forward increasing the understanding on how the alignment can be achieved and giving some examples of the benefits of improved alignment.

One argument against the early alignment of SCM with NPD might be that the product design is determined by desired product functionality and thus customer needs. As such, no supply chain issues should be taken account during the early stages. However, one can question, how valuable is a product, which is delivered late, or product, to which you cannot get any spare parts, even though it would be otherwise perfect? Consequently, these issues must be taken account already at early stages of new product development projects. This is especially relevant in industrial markets, where the products are usually meant to be used in production of other goods and services.

6.3. Limitations and critical review

The case study gave indicative results of how companies make NPD decisions and how these decisions may affect SCM. Furthermore, based on the results it is possible to assume how these decisions should be made in order to improve the alignment between NPD and SCM. However, there are a number of limitations related to the results. First of all, the results are found on a limited number of interviewees from limited number of companies. Furthermore, there might be errors related to interviewees and interviewers.

The sample included only nine respondents from three companies. Consequently, generalizing the results into wider context is problematic. Also Saunders et al. (2009, p. 158) note this limitation related to small number of cases when conducting a case study. As a result, as this thesis being a preliminary study for a larger research, the future research should involve more cases or even some quantitative methods in order to improve the external validity of the results.

Furthermore, there might be limitations regarding to participant error and bias. For example, the interviewees might have said what they thought their colleagues or supervisors wanted them to say. However, the likelihood of this situation is tried to minimize telling the interviewees about the anonymity of the results. On the other hand, there might be also limitation regarding to subject error and bias. The questions may have formulated so that they guided the interviewee to respond in certain way. In addition, the responses may have interpreted faulty even though the transcribing was made by external service provider.

In addition to limitations, some subjects of criticism can be presented. Firstly, the interviews were more like discussions and the interviewees were allowed to tell issues they thought important. Consequently, all the interviewees might not have focused on same things. Furthermore, the questioning frame evolved through the writing process and as such, some issues might not have discussed with every interviewees. On the other hand, the thesis was an exploratory by nature and thus, semi-structured interviews are an acceptable source of data (Saunders et al. 2009, p. 321). Furthermore, another subject of criticisms is the use of proper language and general definitions. In some cases it is possible that the interviewee has understood the question incorrectly and thus some of the results might be incomplete.

6.4. Future research

Since this thesis is a preliminary study, one of the targets of this thesis was to find future research needs. As it is already noted several times, there are no previous studies on how supply chain is made up as a result of new product development decisions. This thesis offers some insights into issue, but further studies are still needed since the focus of the study is so extensive. Especially, a wider study that could include also quantitative analysis would be beneficial to secure the validity of the results.

The focus of this study is on sourcing and purchasing, but also downstream activities in supply chain should be investigated in more detail. For example, the better alignment of NPD and SCM could also largely improve delivery performance and logistics in general. Furthermore, the reverse supply chain is left without large attention in this thesis. However, the resource crunch is one of the global megatrends and thus companies should pay more and more attention on the reverse supply chain already during the new product development project. At the moment there are already researches on environmentally conscious design and life-cycle analysis of the product and on the other hand researches on reverse logistics and network design (Srivastava 2007). However, the integration of these two research streams in new product development project could offer interesting insights. Based on the case study results, these issues are not taken account at the moment in companies.

In addition, the revised framework illustrated in chapter 5.2 takes a stand on the upper level strategies and their impact on a new product development project. Since the focus of this thesis is mainly on project level decisions, a further research would be needed to study the link between the new product development project and the upper level strategies. Especially, the link between the supply chain strategy and the new product development project would be worth of investigation from the view of NPD and SCM alignment.

This thesis studies the decisions related to supply chain of a new product. Due to constant increase of service business, also the formation of new service’s supply chain should be subjected for further research. The decision perspective used in this thesis would be beneficial in that context too.

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APPENDICES (1 PIECE)

APPENDIX 1. Questioning frame

0. Background

a) Personal background
b) Company overview
c) Products

1. New product development process

- Would you describe your new product development process?
- Who is involved in the process and when?
- What is your function's role in new product development?
- In which stages are supply chain issues discussed?

2. Project management

- How is new product development project managed / coordinated?
- How does the communication happen?
- Do you use any planning methods during the new product development (DFX, value engineering, target cost)?

3. Concept development

- What is the starting point of new product development project?
- What targets are set for the development project?
- Do you ever discuss what kind of supply chain would be desirable for new product?

4. Product development

- Can you tell more about your product architecture/modularity?
- How is the number of variations determined?
- Do you try to exploit commonality? How?
- Do suppliers participate in the NPD project? How, when?
- Do you take account the reverse supply chain? How?

5. Selecting suppliers and components

a) Sourcing (components with own design)

- How do you make "design or select" decision?
- Who designs outsourced items?
- How do you select suppliers?

- How often do you change suppliers?

b) Material selection and standard components
   - How do you select materials and standard components?
   - How do you select material and standard component suppliers?
   - How often do you change material and standard component suppliers?

6. Supply chain management
- Do you think somebody in the company manages the whole supply chain? Who?
- How do you manage supply chain risks?
- Who makes the most determining decisions affecting supply chain?
- What is your role in configuring supply chain?
- What do you think, are decisions related to supply chain made coordinated?

7. Evaluation
- Do you evaluate new product development projects afterwards? How?
- Do you evaluate new product supply chain afterwards?
- How should the new product development process be improved?
- What do you think, are supply chain issues taken account well enough during new product development?